The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVIII No. 3 MARCH, 1957

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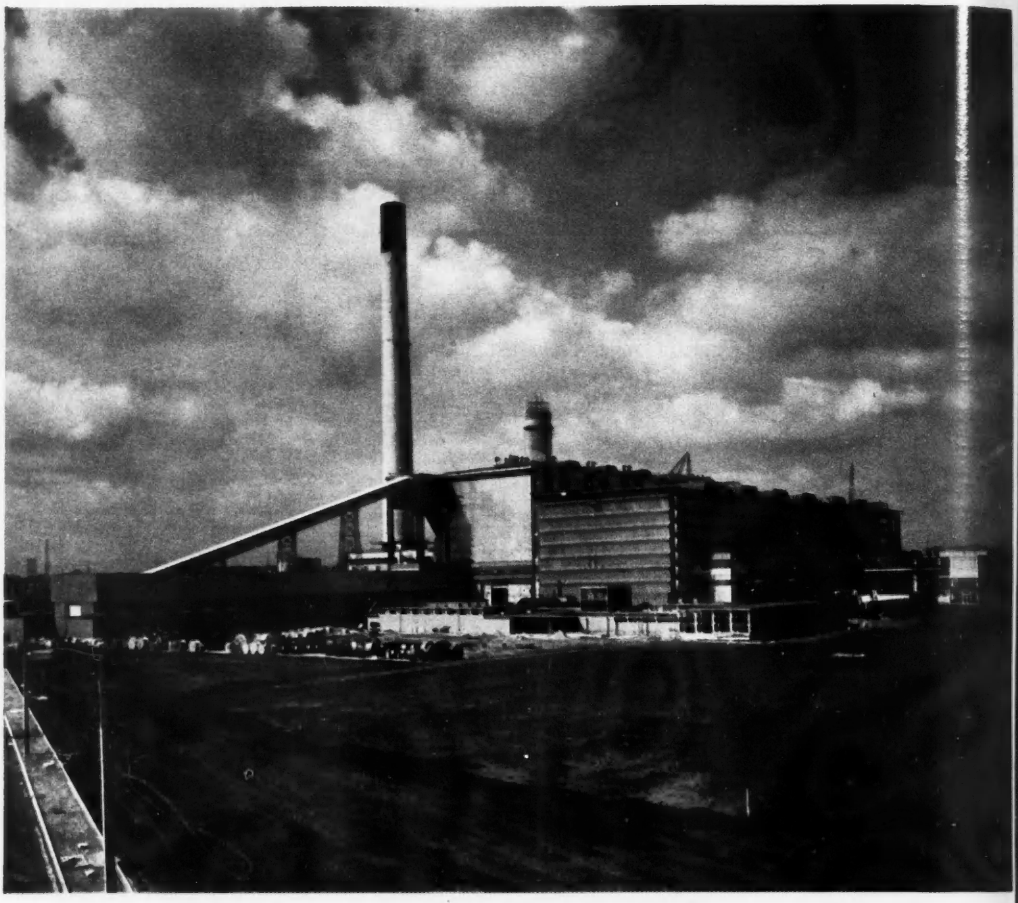

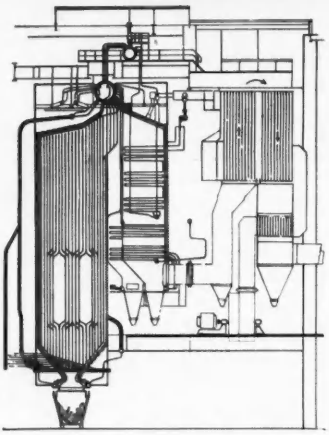

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *SOLUBLE CORES FOR INVESTMENT CASTING*

A recent paper describes the methods available for overcoming the problem of non-retractable cores in investment casting. There are three techniques available to provide a solution, i.e., (1) split-section retractable metal cores, (2) split-section patterns, fixture-welded or cemented to form the whole pattern, and (3) water-soluble cores. The first method usually causes trouble because of wax flash into the parting lines. However, in most cases the flash can be hand-trimmed from the passage in the pattern, and this condition is not of major importance in evaluating these techniques. Where difficult internal contours are encountered, it is usually impossible satisfactorily to section the core for removal. Trouble may also arise in the case of parts where the cored section is too small to be subdivided for extraction. The second method is frequently used with both wax and plastic patterns and is quite a successful technique. In joining, a good seal is necessary to avoid penetration of the dip coat. The third method is to be used only in cases where the two other methods are not applicable, since it will not otherwise be economical. Initial efforts to produce water-soluble waxes were concentrated on the use of carbo-wax materials, but it was soon realized that these waxes were too weak to carry the applied loads, and experiments were made with various fillers, silica flour being found to be a suitable filler for small parts. An especially good core material was a combination of carbo-wax and powdered mica, injected at temperatures of from 150 to 155°F and at pressures of from 1000 to 1500 psi.

● *USE OF THE HALL EFFECT FOR TORQUE MEASUREMENT AND CONTROL*

A recent patent specification outlines the utilization of the Hall effect in a semiconductor for the measurement of torque in electrical machinery. The basic principle consists of exposing a semiconductor element to the action of an influencing magnetic field associated with, or equivalent to, the magnetic field of the electric machine, and at the same time passing through the semiconductor element an electric current equal or proportional to the load current. The Hall voltage set up in the transverse direction of the semiconductor element will then be a measure of the torque of the machine. This voltage may be utilized to act, either directly or through amplifiers, on an indicating or recording instrument, or on a control or regulating device. The semiconductor element may be located in the air gap of the machine, and the load current may be passed through the semiconductor either directly or through a shunt or transformer. It is claimed that such a device has many advantages over conventional instruments, particularly because the measurement obtained includes the power loss caused by bearing friction and windage. In rolling mills the device permits determination at any moment of the deforming torque and the deforming work required for a particular operation. In sheet, strip, or wire-rolling mills, the device can be used for maintaining constant tension of the sheet by varying the speed of the winding motor in accordance with the increase in winding diameter of the reel.

● *MEASUREMENT OF MAGNETIC FIELD STRENGTH BY A VIBRATING-COIL PROBE*

Vibrating-coil methods have at various times been employed for measuring the strength of magnetic fields. In homogeneous fields, rectilinear oscillations of the coil produce sinusoidal induced voltages, provided that the oscillatory movement is sinsusoidal, while, in the case of rotary oscillations, a second harmonic is produced, even in a homogeneous field. A new vibrating-coil probe has recently been developed in which the area required for field measurement is kept especially small, in order to increase accuracy of field measurement. The measuring coil is wound on an elongated thin-wall metal tube-former of rectangular cross-section, two pairs of parallel bronze wire springs being fitted to the casing of the instrument, forming a resilient suspension for the measuring-coil element. On the lower end of this element two coils are fitted, their longitudinal axis coinciding with that of the measuring-coil former. At the junction of the two coil units another bronze wire spring is fitted. The constants of these springs are matched in accordance with the associated masses, so as to produce approximately equal natural frequencies and to avoid longitudinal vibrations within the oscillating system. The casing of the vibrating probe forms a heavy massive body, both to prevent oscillations from affecting the other parts of the

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apparatus and to prevent the oscillations being influenced by vibration. This is of particular importance, as the mechanical oscillating system determines the frequency of oscillation solely through its natural frequency. The closed loop of a control coil, valve oscillator, driving coil, and mechanical oscillation system forms an electro-mechanical oscillating circuit which vibrates at the resonance frequency of the mechanical oscillating system in the same way as a driven tuning fork.

● *SPOT WELDER FOR METAL FOILS AND FINE WIRES*

A special type of spot welder, developed for welding metal foils and fine wires, delivers a controlled high peak current at the electrode tip and repeats the exact discharge for each succeeding weld, the energy being stored in a capacitor bank for intermittent use by welding electrodes. The current at the electrode tips may have a high peak value of up to approximately 10,000 A, the discharge duration varying from 0·003 to 0·0166 sec for each spot-weld. The storage capacitor bank is supplied with approximately 1500 V d.c. by a full-wave rectifier. The capacitor bank is connected to the primary of a welding transformer through a thyratron, which is normally biased below cut-off, so that it functions as a switch when the bias is momentarily removed. When the switching action of the thyratron takes place, the capacitor bank is discharged through the primary of the welding transformer, allowing current to flow in the secondary and energizing the electrodes closed on the workpiece. Welding pressures range from 0·5 to 18 psi and are obtained by adjusting a metal bellows unit which supports the floating lower electrode. The design of this unit is such that, when the upper electrode is depressed or lowered by pressure applied to a foot-pedal, it halts the downward electrode movement and actuates a snap-action switch. This initiates the welding cycle when the parts to be welded are under a predetermined pressure. Where the parts to be welded comprise extremely thin sheet or foil materials, the pressure may amount to less than 1 psi. Materials which have been welded with this machine include nickel to molybdenum, brass to brass, platinum, iridium, palladium, phosphor bronze, etc.

● *NON-DESTRUCTIVE TESTING OF FERROMAGNETIC WORKPIECES*

In the non-destructive testing of metallic workpieces it is common practice to use the eddy-current method, which consists of producing eddy currents by induction in the piece to be tested. This method has proved suitable for the testing of parts consisting of non-magnetic metals, such as aluminium or other light metals and purely austenitic steels. However, difficulties are encountered in applying the method to the testing of workpieces having ferromagnetic properties, as it has been found that fault indication is so greatly influenced by magnetic effects due to local cold deformation or varying heat treatment that the indications obtained are quite unreliable ; furthermore, even small local cold deformations of the piece to be tested may produce fault indications which are just as positive as those given by small cracks or deviations in the composition of the material. According to a recent invention, this difficulty can be overcome by premagnetizing the piece to be tested at the measuring point by means of a magnetic field of a strength of at least 2000 ampere-turns per centimetre. It is claimed that, in this way, it is possible to avoid substantially all spurious indications in the testing of ferromagnetic workpieces, so that, for example, cracks and other faults in cold-drawn tubes can easily be detected. Premagnetization also makes it possible to increase the frequency of the alternating current employed for the generation of the eddy currents, thus increasing the sensitivity of measurements. Because of the premagnetization employed, permeability is reduced, and hence the depth of penetration of the eddy currents is increased, so that it is possible to use frequencies as high as 200 cps.

● *JOINTS BETWEEN IRON AND LIGHT METALS*

The adherence of light metals, particularly of aluminium and its alloys when cast on iron and steel, is known to involve difficulties, and special methods must be used to enable a casting bond to be made which has sufficient adherence. A recently patented method is based on the discovery that a good bond can be obtained by employing a bonding layer consisting of an alloy which contains at least one element of the group comprising tin, zinc, and cadmium, and at least one element of the group consisting of the rare-earth metals, alkali metals, and alkaline-earth metals. It is claimed that a particularly good bond is obtained when the cleaned iron surface is dipped first into a melt of one of the above metals, to which a mixture of rare-earth metals including cerium in an amount of 0·5% has been added. The light metal is then cast on the interlayer. It is recommended that the iron part is moved about in the molten alloy which is to constitute the interlayer. The light metal can be cast on the component either at room temperature, or preferably at a temperature of 100 to 150°C, in order to eliminate any moisture which may adhere to the surface. Casting need not immediately follow the application of the interlayer, but the parts provided with the interlayer may be stored and have light metal cast around them later on. A

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typical example is the casting of an aluminium part on a steel bolt, which is first dipped in an alloy of 74·5% tin, 25% zinc, and 0·5% rare-earth metal mixture containing cerium. The molten alloy is maintained at 700°C and the bolt is dipped in and moved about in the melt. After cooling, the bolt is placed in a chill mould and cast around with pure aluminium.

● *VISUALIZATION OF LOW-DENSITY GAS FLOW*

The usual methods of flow visualization, e.g., shadowgraphs and schlieren interferometer, are not applicable in gases of low density, where pressures of less than 1 mm Hg are encountered. There has been considerable interest, therefore, in developing a new technique which may be used in low-density wind tunnels. A recent research report refers to a new method which is based on the absorption of ultraviolet radiation by oxygen, the amount of absorption being a function of the density of oxygen. Consequently, the intensity of radiation passing through a region of high density will be less than that passing through a region of low density, and shadows, which can be photographed, will be formed, indicating flow configuration. From the research conducted it was concluded that density measurements are possible by this method, which, however, is subject to a number of limitations. Thus, long effective radiation paths are necessary through density fields of small gradients, but, with a radiation source of finite intensity, the exposure time necessary in high-density regions with long radiation paths is prohibitive. Moreover, the photographic detection of the transmitted radiation with present-day commercial ultraviolet-sensitive emulsions requires a large number of calibrations, and numerous flow photographs must therefore be taken to provide sufficient data for the statistical analysis necessary because of variations in emulsion response. In order to make the method a practical proposition for wind-tunnel use, it is considered essential that a photo-tube be used instead of a camera for detection purposes. Other improvements considered necessary are the use of fluorescent screens to facilitate optical alignment and focusing, and a simplified optical system.

● *HYDROGEN-INDUCED BRITTLE FAILURE OF HIGH-STRENGTH STEEL*

The problem of delayed brittle failure of high-strength steel has become increasingly important, especially in electroplated aircraft components, the trend being towards the use of steels of higher strength levels. Investigations have emphasized three principal observations with regard to such failures, i.e., (1) there is a time delay after the parts have been subjected to load, before failure occurs, (2) failure usually occurs at loads well below the design limit, and (3) hydrogen in excess of the residue from the steelmaking process is generally necessary for failure to occur, excess hydrogen usually being absorbed by the steel during pickling or electroplating. A recent investigation aims at the determination of the basic mechanism of such failure, and, on the basis of experimental work, it is concluded that delayed brittle failures can be produced easily in unnotched tensile bars if the specimens are continually charged with hydrogen while under sustained loads, and that the ultimate tensile strength appears to be the most important metallurgical variable in delayed brittle failure. There is a minimum stress for producing a failure ; at stresses higher than this minimum, the time for failure depends on the applied stress, the minimum stress for failure and delay times being functions of ultimate tensile strength, and both decreasing with increasing strength levels. It was also observed that both these factors at higher stresses are insensitive to variations in the composition and structure of the steel. An important result of this investigation is that a qualitative relationship has been established between hydrogen content, ultimate tensile strength, applied stress, and the time for delayed brittle failures to occur.

● *EFFECT OF CERAMIC COATINGS ON THE CREEP OF ALLOYS*

Refractory-type ceramic coatings are finding wide-spread application in metal parts exposed to high temperatures, e.g., in aircraft engines, protecting the metal against the various corrosive atmospheres in which these parts normally operate. It has been found that these ceramic coatings also affect the creep rates of some alloys under stress at high temperatures and, in order to clarify the situation, a special study was recently carried out with a view to determining the creep behaviour of coated parts under different temperature/stress conditions. Results indicate that under some conditions a coating can reduce the creep rate by as much as 50%, whereas, under other conditions, a deleterious effect is observed. The tests were made with a coating containing cerium oxide for refractoriness, and this coating material was applied to specimens machined from thin sheet-metal. The alloys coated included two 80% nickel 20% chromium alloys differing significantly in manganese, iron, and silicon content. Both coated and uncoated samples were tested in a conventional controlled-temperature furnace designed for creep testing. At 1975°F and 600 and 1200 psi stress, the ceramic-coated specimens showed the greatest reduction in creep rates, compared with the uncoated specimens. Under these conditions, the beneficial effect of the coating on the creep behaviour of both these Ni-Cr alloys

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is sufficient to be of practical importance. However, while at 1800°F and 2200 psi the initial creep rate of ceramic-coated specimens was found to be below that of the uncoated specimens, the coated specimens after some 20 hours showed an even greater rate of increase in deformation than the uncoated specimens, and fracture of the coated specimens, when it occurred, usually took place during the first 20 to 30 hours of the test.

● *NOVEL CIRCUIT-BREAKER EMPLOYING THE PINCH-EFFECT*

A recently patented circuit-breaker is based upon the well-known pinch-effect to which a liquid conductor is subjected at high currents. In the new switch a vertically placed conductor is interrupted by a gap filled with mercury, the lower part of the conductor being furnished with a central cavity large enough to contain the entire mercury content of the switch. A current flowing in the conductor through the mercury in the gap exercises a pinch-effect, tending to move the mercury inwards. As the current increases, so also does the force due to the pinch-effect and, when this force exceeds the surface tension of the mercury, the latter is suddenly squeezed into the centre of the gap and runs into the central cavity, thus interrupting the current. The pinch-effect may be increased by introducing a magnetic material in the path of the magnetic flux due to the current. Instead of using mercury, a fusible metal such as tin-lead alloy may be used, the alloy remaining solid under normal current conditions, but melting before an overload condition arises. In order to accelerate the ejection of mercury from the gap, a gas under pressure may be made to act upon the mercury at the instant when the pinch-effect occurs. In this connection, it is stated that the use of a gas under pressure also has the advantage of raising the arcing potential when the switch opens, and that the use of an inert gas prevents oxidation effects. It is claimed that a switch of this type has been found capable of readily breaking a d.c. current of 4000 A.

● *IMPROVED MAGNETIC IRON-COBALT-VANADIUM ALLOY*

It is claimed that substantial improvements in magnetic amplifiers, switching and memory devices, and power transformers are now possible as a result of a recently developed magnetic alloy. This material will permit reductions in the size of magnetic components without any sacrifice in performance, and will facilitate the design of new components with greatly improved performance characteristics. The new alloy has a number of exceptional properties, including higher permeability and lower hysteresis losses at higher flux densities than any material heretofore available. The composition of the new material is 49% Fe, 49% Co, and 2% V. This composition is not in itself new, but the improved characteristics achieved are due to the special way in which the alloy is produced and worked, resulting in a reduction in hysteresis losses by a factor of ten, as compared with the original material. Maximum permeability is now 66,000 at 20,000 gauss, remanence is 21,500 gauss, coercive force is 0·26 oersted, and saturation is 24,000 gauss. Core losses are under 6 W/lb at 400 cps at a flux density of 100,000 lines per square inch. The hysteresis loop is rectangular, with a flux swing of 45,500 gauss from minus remanence to plus saturation. These outstanding properties have been achieved by using commercial materials of the highest purity, by melting in a controlled-atmosphere furnace, and by subjecting the resulting alloy to a prescribed schedule of rolling and heat treatment in a magnetic field. The material is reported to be so malleable that it can be cold-rolled from 0·09 to 0·003 in. without intermediate anneals and without losing its ductility. Power-transformer cores of 0·004 or 0·002 in. tape can provide an output more than 30% greater than comparable grain-oriented silicon-steel cores.

● *ELECTRICAL CONDUCTOR ELEMENTS FOR THERMOELECTRIC CONVERSION OF ENERGY*

A recent invention aims at the provision of electrical conductor elements with low electrical resistivity, and with a high power output when used for the thermoelectric conversion of energy. The invention consists of an electrical conductor element composed essentially of lead and tellurium, the lead content being either in the range of 61·9 to 65% for an electrically negative element or from 58·0 to 61·8% for an electrically positive element, the balance being tellurium in both cases ; the metallic impurities in the element do not exceed 0·01%. It is stated that these ranges are based upon investigations which show that the polarity of the thermal electromotive force of the element reverses between the lower limits of 61·9 and 61·8% lead. The investigations have also shown that, when the lead content exceeds the upper limits of 65 and 58%, the lead-tellurium combination does not provide electrical conductor elements of commercial value. A conductor element of the type described may be combined with any electrically conductive material as the second element to form a thermocouple. It is claimed that stainless steel is particularly suitable, and that such a thermocouple operates with a thermal efficiency as high as 2%. A thermocouple can also be formed by joining an electrically negative and an electrically positive element of the compositions given above.

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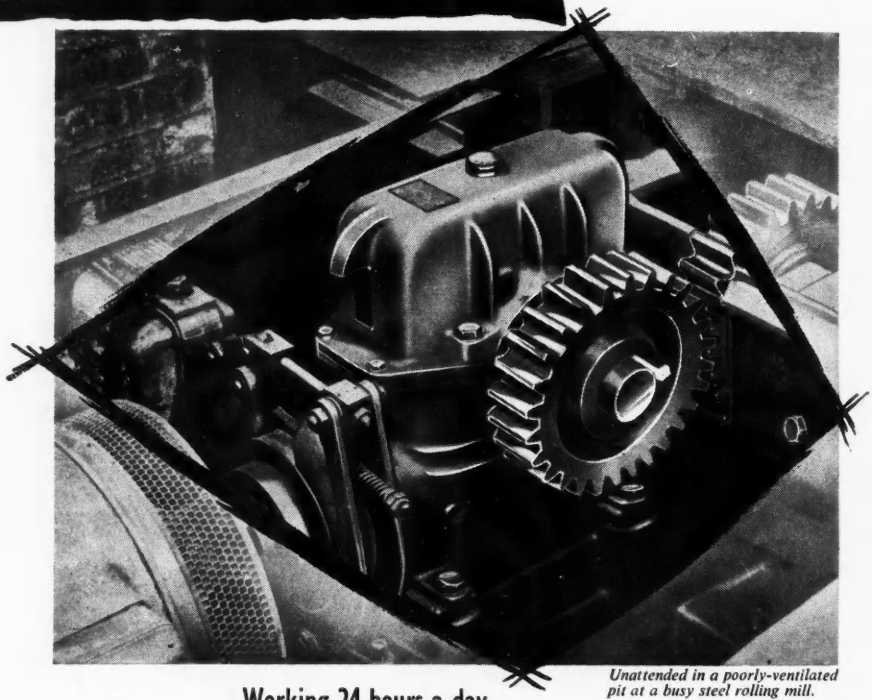

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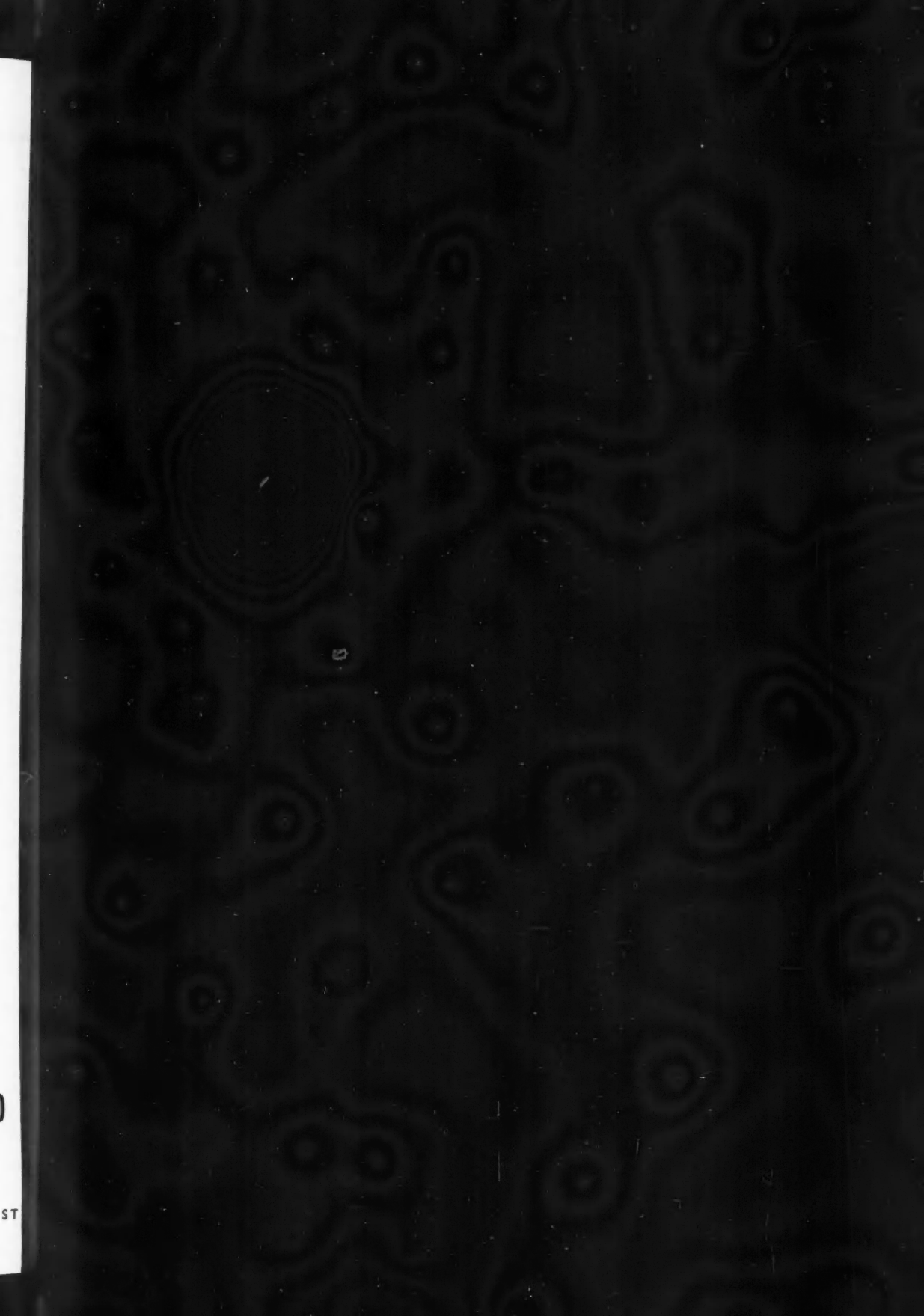

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A Method of Estimating the Costs of Maintenance Painting

By R. F. WILLIAMS and J. H. COGSHALL. (From *Corrosion, U.S.A.*, Vol. 13, No. 1, January 1957, pp. 19-27, 14 illustrations.)

By establishing an arbitrary average base of painter man-hour productivity, and then assigning different factors for the effects produced on painting costs by a number of variables, it has been found possible, as described in this article, to estimate with considerable accuracy the cost of industrial maintenance painting. The method can be used satisfactorily even by those without a wide knowledge of painting technology and produces closely comparable cost predictions by different estimators.

ESTIMATION of the cost of industrial painting jobs is an operation for which there is little precedent in the literature and no recognized standards of procedure. For this reason it is not surprising that there is a number of widely differing approaches to the problem. This is particularly true for plants in the process industry, such as chemical manufacturing plants, in which paint protection serves the dual purpose of improving appearance and providing corrosion protection against severe spillage and fume conditions. As a result, there is considerable variation between the estimates for any individual project produced by one estimator and another.

Estimation of painting costs consists of two operations, i.e., calculating the square footage to be painted, and the cost of painting this area. Calculation of paintable square footage is a reasonably straightforward matter. The areas of tanks and process vessels may be calculated from common geometrical formulae or taken from tables, with an additional calculation or percentage allowance for nozzles and fittings. In the field of residential or architectural painting, there are certain established factors which may be given to allow for areas of window openings, doors, stairs, roof peaks, and other recurrent structural characteristics. It has been found, however, that these factors are not usually applicable to equipment and structures which prevail within the process industries. Furthermore, it has been established that estimating square footage by aggregate tonnage of steel is also unreliable for the process industries, using currently published figures. There is sufficient standardization of design and equipment in the process industries to establish reliable factors for recurrent constructions used within the industry, but this is beyond the scope of the present paper.

Area calculations, once made for any process area or major item of equipment, are made a permanent record. Thus, there is no need for a recalculation for future repainting operations, provided that no alteration in the process or equipment has occurred in the ensuing period.

During the past three years, following on a programme conducted to improve the efficiency of painting, the durability of appearance, and the corrosion protection of applied coatings, the Wyandotte Plant of the Pennsylvania Salt Manufacturing Company has been devoting considerable attention to studying the influence on painting costs of various pertinent conditions. During this period, four different methods of assessing these conditions were experimentally used in connection with Wyandotte painting programmes. The outcome of this work is what is called the Wyandotte method, in current use in this plant, in which the greatest variety and severity of corrosive environment are present. The principles of this method have been used and proved over the past three painting seasons and, by actual comparison of job estimates with their actual cost, have been found to be reliable to within an average of 2% for any season's painting.

PRINCIPLES AND METHOD OF ESTIMATION

The procedure consists simply of a quantitative rationalization of the effects upon total painting costs of the various conditions which tend to increase costs, as follows:—

(1) *Paint Material* :—

It is recognized that industrial painters are thoroughly experienced and familiar with the application of oil-base, oleoresinous, or oil-derived paints. Faster-drying synthetics and special coatings often required for chemical exposures require special techniques and precautions which must be observed in their application. In the use of these materials the costs of paint application increase.

(2) *Application Procedure* :—

It is obvious that painting costs will increase with the number of coats specified in the painting system. In addition, the method of application of each coat has a bearing on costs. Of the application methods most common in industrial painting, it has been found that brushing is more expensive than spray application. Therefore, in estimating painting costs, not only the number of coats to be applied, but also the method of application must be considered. The first coat applied, however, is always brushed, to ensure mechanically adequate adhesion to the substrate. Some coatings do not lend themselves to spray application, and it is found that roller applications in these cases compare favourably, both with respect to cost and time, with spray applicators.

(3) *Surface Condition* :—

The initial condition of the surface to be painted profoundly affects the cost of surface preparation. Surfaces with large areas of heavy, dense, adherent rust scale, or of blistered, cracked, and peeling paint, will entail much higher surface-preparation costs than surfaces on which the previously applied paint film is continuous and intact, but possibly soiled. They will also show higher

Fig. 1. Surface with loose dirt, easily removable by wire-brushing.

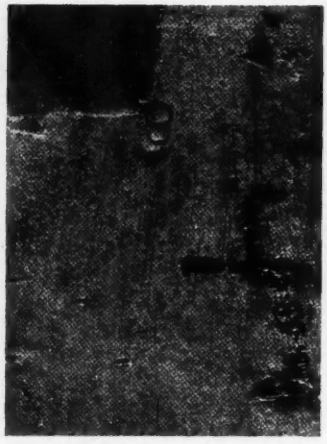


Fig. 2. Surface with light pin-point or powdery rust.

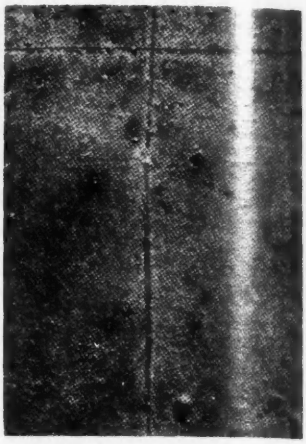


Fig. 3. Surface with occasional blisters and rust patches.

costs than bare steel surfaces covered with light, powdery, and relatively non-adherent rust. In subsequent quantitative consideration of these effects on costs caused by variation in surface condition, no distinction is made among the various methods of surface preparation. It has been generally found and assumed that, for a comparable finished quality of surface preparation, costs by one method will be approximately comparable with costs by other methods.

(4) *Pretreatment* :—

In many exposures within the process industries, pretreatments after surface preparation and before priming are required for paint durability. Surfaces on which there is suspicion of moisture will be benefited by an alcohol wash. Surfaces with acidic contaminations in many cases will be benefited by neutralizing washes. In such treatments, it will often suffice simply to wash, rinse, and dry surfaces to accomplish the desired results ; in other instances, an actual scrubbing of the pretreatment into the surface, to penetrate and loosen soilage, is required. Treatment and method of application will affect these costs.

(5) *Surface Configuration* :—

It is axiomatic that the costs of painting any unit surface will vary tremendously, depending on whether the surface consists of an unbroken, continuous plane or, at the other extreme, of an interlaced complexity of light structural members. Therefore, the type of equipment or structure painted, especially insofar as it deviates from the simplicity of a plane surface, must be considered in estimating.

(6) *Rigging* :—

It must be recognized that the most rapid painting is performed when the workman is standing on a solid footing, with completely unrestricted freedom of movement. However, there are few industrial painting jobs where the complete operation can be carried out from the ground. When the workman is required to employ ladders, slings, staging, or rigging, his speed and continuity of application are necessarily reduced, thus increasing the costs of painting. This includes the cost of installing and removing the required staging and rigging equipment.

(7) *Interference* :—

Rare is the painting job in an operating manufacturing plant in which painters are allowed to proceed with their work to completion without interruption. Painting schedules necessarily are subordinate to operations ; in many instances, painters must wait for completion of the preliminary operations required by other maintenance crafts. Such interruptions are wasteful of painter man-hours and must be considered in costs. Inclement weather also affects the continuity of painting operations.

(8) *Environment* :—

In any painting operation, and especially those in the chemical industry, workmen may be required to conduct their operations in areas with unpleasant fume or temperature conditions. The use of masks or protective clothing hampers the speedy conclusion of operations, and the temporary installation of relieving exhaust fans or blowers adds to the cost of the maintenance operation.

(9) *Posture* :—

It is recognized that any workman will work most efficiently when he can always maintain a comfortable position with unrestricted movement. If working conditions require him to work in a cramped or unnatural position, speed of operation will be sacrificed, if quality is to be maintained.

All the above factors which influence painting costs are well known and recognized. The only reason for presenting them here is to provide a check list, to ensure that no pertinent factor is overlooked during estimation. Under painting conditions as they exist at the Wyandotte plant, it has been determined that these nine factors are sufficient to estimate painting costs properly. It is appreciated that, in other plants with somewhat different conditions, certain of the factors here considered might conceivably be of less importance, and that other factors not included should be added to the list.

For the purpose of estimating painting costs, it is first necessary to establish an average base of painter man-hour productivity. This base productivity was arbitrarily established as the rate at which an average and typical painter within the Wyandotte paint crew would complete a " basic " 100 sq ft of surface. This basic surface was defined as a continuous vertical area of plane surface

Fig. 4. Surface with moderate blisters and rust.

Fig. 5. Surface with severe blisters and rust.

Fig. 6. Surface with severe blisters and scale.

which was (1) entirely at the painters' trunk height ; (2) in the open, thus allowing unrestricted movement ; and, (3) of such surface condition that only minimum hand brushing would be required prior to paint application.

The basic application was designated as a one-coat brush application of an oil-base, oleoresinous, or oil-derived coating applied under ideal weather and other conditions for paint application. Four years ago, at the outset of this study, this base productivity rate was established from observation and interpolation of actual completed paint jobs to average 6 man-hours per 100 sq ft. In the following three years, this base productivity average has fallen from 6 to 4 man-hours. This gradual decrease in labour consumption is attributable in large part to increasing efficiency developed by the paint crew, as a result of the practice and the instruction of the educational programme which accompanied the Wyandotte maintenance painting evaluation and standardization programme. Other factors are (1) the increasing familiarity by workmen of the new special materials which they are sometimes required to apply, and (2) the adjustments in the base productivity rate found to be necessary to adjust the estimated costs to actual costs.

It is recognized that even the current productivity of 4 man-hours per 100 sq ft is high. Even when taking into consideration the fact that the turn-over in the paint crew is no less than normal for chemical industrial painting, and that it is necessary that sufficient time be taken in application to ensure highly durable work of good quality, it is clear that this productivity rate can be still further reduced. Reduction of this rate, without sacrifice of quality of application and durability of applied coatings, is a subject of separate study.

Having thus established this base productivity, it is now necessary to determine the adjustments required for deviations from this ideal base application. For this purpose, a multiplying job factor is determined. When this job factor is multiplied by the base productivity, the anticipated labour usage for any individual paint application will result. To sum up, then, the anticipated labour expenditure for a job is taken at the rate of 4 man-hours per 100 sq ft and the job factor as 1·0, assuming (1) the application of one brush coat of oleoresinous, alkyd, or phenolic paint ; (2) minimum surface preparation ; (3) no wash or rinse ; (4) application to a continuous vertical plane surface at painters' trunk level ; (5) no requirement for scaffolds, ladders, or rigging ; (6) no abnormal interruptions during application ; and (7) unrestricted movement, with painters standing on the ground.

If, however, as is more usually the case, conditions more adverse than those established for the basic rate are encountered, this job factor of 1·0 must be increased, to compensate for the added difficulty of application imposed by the specific conditions. Some typical surfaces are shown in Figs. 1 to 6. By actual labour rate measurements, and by a process of continual factor adjustment to bring estimated costs in line with actual costs, the following schedule of increases due to variations in adverse conditions was obtained :—

(1) *Paint Material* :—

Chlorinated hydrocarbon resin	0·1
Chlorinated rubber, vinyls	0·3
Maintenance neoprenes, epoxys, paints requiring accelerator additions	0·6

(2) *Application Procedure* :—

Basic increase : Spray, 0·2 ; roller, 0·3 ; brush,	0·4
Two coats—one each by brush and spray	0·2
Two coats, brushed (or three coats, of which one is brushed and two sprayed)	0·4
Four coats, three of which are sprayed	0·6
Three coats, brushed (or five coats, of which one is brushed and four sprayed)	0·8
Four coats, brushed	1·2
Five coats, brushed	1·6

(3) *Surface Condition* :—

Loose surface dirt, easily removed by wire-brushing, (Fig. 1)	0·0
Light pin-point or powdery rust (Fig. 2)	0·3
Occasional blisters or rust patches (Fig. 3)	0·6
Moderate blisters and rust (Fig. 4)	1·0
Severe blisters and rust (Fig. 5)	1·5
Severe blisters and scale (Fig. 6)	2·0
Heavy scale	2·5

(4) *Pretreatment* :—

Light rinse or neutralizing	0·2
Scrubbing	0·4
For each wash between coats	0·2

(5) *Surface Configuration* :—

Occasional projections, e.g., bolts, rivets, welds, etc.	0·5
Heavy structural members	1·0
Light structural members	2·0
Lattice, grating, etc.	3·0

(6) *Rigging* :—

Ground and ladders	0·5
Ladders only	1·0
Swing-stage and ladders	1·5
Scaffolding or other complicated rigging	2·0

(7) *Interference* :—

Remote from shop ; outside job	0·1
Slight interference (remoteness, plus outside job)	0·2
Moderate interference (requires coordination with production)	0·4
Heavy interference and interruption	0·6

(8) *Environment* :—

Influence of gas in known offending areas	0·2
Moderate temperature or humidity	0·3
Severe temperature or humidity	0·4

(9) *Posture* :—

Stooping, kneeling, and sitting	0·3
Crawling and reaching	0·6
Lying, crawling, and reaching	0·9

As an example of the use of this method, suppose that, in a particular painting job, the influence of the above nine factors is such that the sum of the required increase factors is, say, 2·9. This aggregate value, when added to the basic job factor of 1·0 gives an overall job factor of 3·9, so that the basic productivity figure must be multiplied by this factor to give an estimate of the man-hours which must be allowed for the job. In this case, on the basic figure of 4 man-hours per 100 sq ft, 15·6 man-hours will be required per 100 sq ft, and it may also be assumed that this particular job is 3·9 times as difficult to do, in terms of labour requirements, as the same area would be under the " ideal " conditions previously postulated.

As the paintable area is already known, the total man-hours required for a job can thus be calculated and scheduled, and the labour cost of the job estimated, together with the amount and cost of material.

It should be noted that, while assignment of values for the various increases is subject to considerable variation in personal judgment, a wide error in any one such assignment will have relatively little effect on the finished estimate. For instance, suppose that the increase for one of the variables in the above example, say, rigging, was adjudged to be 0·5. If, in fact, a factor of 1·0 (i.e., a 100% deviation) more truly represented the actual rigging conditions, the estimate using the figure of 0·5 would be in error by only about 12%. Actually, small personal deviations in judgment in evaluating each factor for the nine different conditions will, according to the law of averages, tend to offset each other.

Practical Results

The effectiveness of the method may be judged from the fact that, in the twenty-two scheduled paint applications in the 1954 programme at the Wyandotte Plant, covering a total area of about 32,500 sq ft of painted surface, the estimated man-hours were 6522, the actual figure being 6517. It should, however, be mentioned that, although the estimates for the entire programme accurately predicted costs, there were some rather wide deviations in specific job costs. In view of these discrepancies, it might be concluded that virtual agreement of the actual overall costs for the season with the estimated costs was purely coincidental. As evidence disproving this conjecture, it should be pointed out that the record for a previous season showed costs in line with estimates to within 2%, although individual job discrepancies varied as widely as those in the 1954 record.

It must always be remembered that the primary objective of the method is the realistic prediction of costs for an entire painting season. In this connection, there are very sound reasons why this method in its present form cannot be used dependably for making individual job estimates, though there is no doubt that adjustments can be made, if desired, to bring individual job estimates closer into line. It is felt, however, that the additional considerations needed to accomplish this are not justified, as current objectives are adequately satisfied by the simpler approach.

Job Deviations

A year's painting programme was examined to determine the type of job for which the greatest deviation occurred. It was found that 24% of all the estimates made, representing only 18% of the area painted that season, showed deviations from the estimate of higher than 30%. These were necessarily the smaller jobs, and the fact that these smaller jobs deviate more from estimates is further verification of the established conviction that small painting jobs, wherever possible, should be avoided or should be combined as larger undertakings. It is also further confirmation of the poor economy of doing any but the most necessary painting under minor repair orders.

The most apparent reason for this departure of small jobs from reasonable estimates is the disproportionate labour time required in setting up to do the job and cleaning up afterwards, compared with actual surface-preparation and application time. Certain job histories are known where these non-productive labour diversions have actually exceeded the labour time required for surface preparation and paint application.

One of the greatest causes of deviation from estimates is found to be the non-uniformity of workmen. A typical paint crew, by painting knowledge and ability, is divided into three or more craft classifications, according to skill, and varies even more widely in efficiency and workmanship. It will be noted that neither the base productivity rate nor the additive adjustments takes into consideration the varying qualities of workman efficiency. Conceivably, this could be done, but it is felt that this would introduce such complexities in estimating that the trouble would be more than it is worth.

On any job which requires the entire paint crew, differences in workmanship from man to man would average out to the base productivity rate used. On a small job requiring but relatively few workmen, the actual base productivity, depending upon the ability of the men, may vary from 3 man-hours to 6 man-hours. This causes deviations of this proportion in a final estimate, which is based upon an average productivity of 4 man-hours.

This Wyandotte method of estimation is currently established and is presented for use only with complete overall painting jobs. Its principles, with adjustment, are equally applicable to spot-repair operations, although the adjustments required to adapt it to this type of work have not been fully worked out as yet.

The Influence of Surface Roughness on the Fatigue Strength of Steels and Non-Ferrous Alloys

By E. SIEBEL and M. GAIER. (From *VDI Zeitschrift*, Vol. 98, No. 30, October 21, 1956, pp. 1715–1723, 14 illustrations.)

From a series of steels and non-ferrous alloys in a specified heat-treated condition, fatigue-test specimens were machined to a specified degree of surface roughness and were tested in push-pull, bending, tension, and torsion. In this article, an attempt is made to establish design formulae for various machining processes from the results of these tests. It is found that there is a limiting surface finish beyond which fatigue strength does not improve, and that a surface-hardening treatment after machining (mechanical or thermal) tends to eliminate the influence of surface roughness on fatigue strength.

BEFORE carrying out fatigue tests on the various steels and non-ferrous alloys listed in Table I, consistency of microstructure was checked by metallographic examination. The testing machines used were push-pull pulsators, Wöhler machines, a Schenck torsion fatigue-testing machine, and an Amsler Vibrophore for the non-ferrous materials. The specimens were uniformly machined over the test length and transition radii, so that most fractures occurred in the cylindrical portion. Emery cloth, down to the finest grade, was used for manual polishing, and a fine-grained or coarse-grained grinding wheel for grinding. For turning operations, the cutting speed (3 to 4 m/min), the cutting-point radius (0·58 mm), and the cutting angle (12 deg.) were kept constant, different surface roughnesses being obtained by varying the feed. Roughness was measured with a Leitz-Forster stylus instrument, and the maximum depth of groove R, i.e., surface roughness, was chosen as the critical dimension, because this appeared more suitable for these tests than the arithmetic mean value (Great Britain) or the r.m.s. value (U.S.A.). The following maximum depths of groove R [μ] were obtained for the various machining methods used :—

TABLE I : Materials used in Fatigue Tests.

Material No.	Material	Composition	State
1a	Medium C-steel	0·45 C, 0·25 Si, 0·65 Mn	annealed
1b			tempered
1c			cold-drawn
2a	Cr-Mo steel	0·34 C, 0·25 Si, 0·65 Mn, 1·05 Cr, 0·20 Mo	annealed
2b			tempered
3	Spring steel	0·70 C, 1·70 Si, 0·70 Mn	tempered
4	Stainless steel	<0·12 C, 0·4 Si, 18·0 Cr, 9·5 Ni, <0·48 Ti	annealed
5a	Nitriding steel	0·34 C, 0·25 Si, 0·60 Mn, 1·1 Al, 1·4 Cr	tempered
5b			tempered ; nitriding depth, 0·15 mm
5c			tempered ; nitriding depth, 0·35 mm
5d			tempered ; nitriding depth, 0·70 mm
6	Brass	58 Cu, <3 Pb, rem. Zn	annealed
7	Al-Mg alloy	5·5–7·5 Mg, 0–0·8 Mn, 0–0·3 Cr	annealed
8	Al-Cu alloy	2·5–5·0 Cu, 0·2–1·8 Mg, 0·3–1·5 Mn	age-hardened
9	Mg alloy	1·5–6·0 Al, 0–2·0 Zn, 0·05–0·5 Mn	annealed

Surface	Steels	Non-Ferrous Alloys
Polished	< 1	< 1
Fine-ground	2	—
Rough-ground	5 to 10	—
Fine-turned	10 to 20	5 to 10
Rough-turned	25 to 50	20 to 30
Very rough-turned	>50	>50

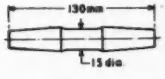
The value of R does not indicate the severity of any machining stresses which may remain in the material and which may affect test results ; however, these stresses are known to have little influence on fatigue.[1] Cutting speed may exercise some influence, insofar as a higher speed improves fatigue properties, but this may be due to the improved surface resulting from a higher speed. Finally, fatigue strength will definitely depend on the shape of the groove, i.e., mainly on the ratio of root radius to depth, or, in fact, of tool radius to feed. This influence does not enter into parameter R. However, for ease of machining, it has been recommended[2] that the ratio of tool radius to feed be standardized to a value of 1·5 approximately.

RESULTS OF TESTS

The tests were run to 10×10^6 load applications for steel, and 60 to 80×10^6 applications for non-ferrous alloys, and the fatigue limit was evaluated by means of the usual S-N curves.

TABLE II : Torsional fatigue strength q_0 of steels with various depths of surface roughness R.

Material No.	Machining			
	Polished		Roughed	
	R [μ]	q_0 [kg/mm²]	R [μ]	q_0 [kg/mm²]
1a	<1	15·0	35	15·0
2b	<1	28·0	50	27·0
3	<1	41·5	25	36·5



Testpiece

The results shown in Table II and in Figs. 1 to 4 indicate that, after a certain critical roughness R_0, which is independent of the type of loading but dependent on the metallurgical structure, has been exceeded, there is a linear drop in fatigue limit with the logarithm of depth of roughness R. For tempered materials the value of R_0 is about 1 to 2μ, and for annealed materials 4 to 6μ. Obviously, the more sensitive tempered materials have a much finer grain size than annealed materials, and this may be the decisive factor, although no quantitative relationship between R_0 and mean grain size can be given.

The possible influence of machining stresses was

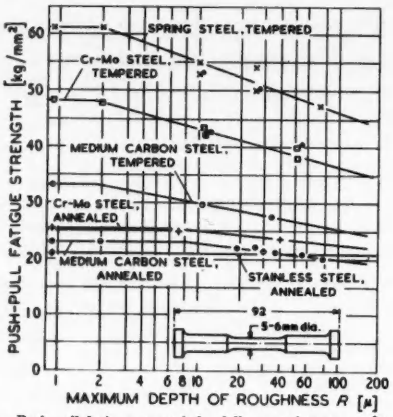


Fig. 1. **Push-pull fatigue strength for fully reversing stress of various steels as a function of surface roughness R.**
The measured values marked with flags indicate specimens annealed in vacuum at 500°C after machining.

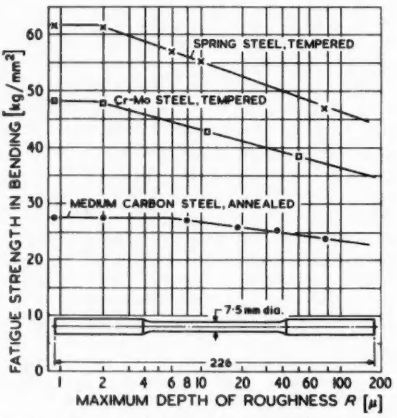


Fig. 2. **Fatigue strength in fully reversing bending of various steels as a function of surface roughness R.**

checked by stress-relieving a number of specimens in vacuum at 500°C after machining ; it was found that fatigue limit did not vary, except in the case of the spring steel (material No. 3 in Table I), where the high stress-relieving temperature probably exercised some further tempering effect (Fig. 1).

Non-ferrous alloys exhibited similar tendencies (Fig. 4), as far as can be judged from the limited number of materials tested, all of these being wrought materials, either drawn or rolled. Cast materials may behave quite differently. The wrought aluminium alloys (materials Nos. 7 and 8 in Table I) had a critical roughness R_0 of about 5μ in push-pull, irrespective of whether they were annealed or age-hardened. The fatigue limit of the magnesium alloy (material No. 9) remained constant up to a roughness of 22μ, even though previous tests have shown magnesium alloys to be highly notch-sensitive.[3]

Conclusions

(1) The drop in fatigue strength with increasing surface roughness is the same with push-pull tests as with fully reversing bending. This is particularly apparent when the surface fatigue factor m (i.e., the ratio of the fatigue strength of a machined specimen of roughness R

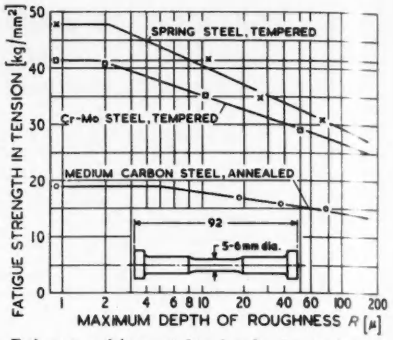


Fig. 3. **Fatigue strength in repeated tension of various steels as a function of surface roughness R.**

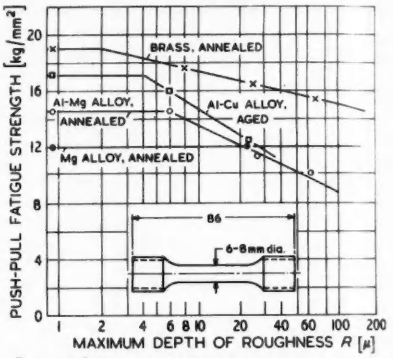
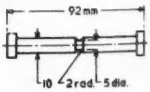


Fig. 4. **Push-pull fatigue strength for fully reversing stress of various non-ferrous alloys as a function of surface roughness R.**

to that of a polished specimen of roughness R less than 1μ) is plotted as a function of roughness R (Fig. 5). Hence, the influence of surface roughness on fatigue strength is independent of the stress distribution or the stress gradient inside the testpiece and presumably also of its size. This inference was checked by tests on notched specimens (of material No. 3 in Table I), the notch being of the dimensions shown in Table III, when it was found that the results conformed to the scatter in Fig. 5, confirming earlier work in which a small semicircular notch was cut into the root of a larger semicircular notch, the effect of the combined notch being found approximately equal to the product of the effects of the two separate notches.[4]

Table III : Push-pull fatigue strength f_i of notched specimens of material No. 3 (Table I), with various depths of roughness R.

Type of Notch	R [μ]	f_i [kg/mm²]	m
Polished	<1	40·5	1·0
Ground	3 to 4	37·5	0·93
Turned	6 to 8	36·0	0·89



Testpiece

(2) Superimposed static tension makes the material more sensitive to surface roughness (Fig. 6). The experimental points in Fig. 6, representing results for two materials, have been connected by straight lines as a first approximation ; it can be seen that the lines for each material converge towards the region of static compression, i.e., with smaller static tension or increasing static compression, surface roughness gradually becomes of less importance. It is known that ductile materials under high superimposed static compression do not

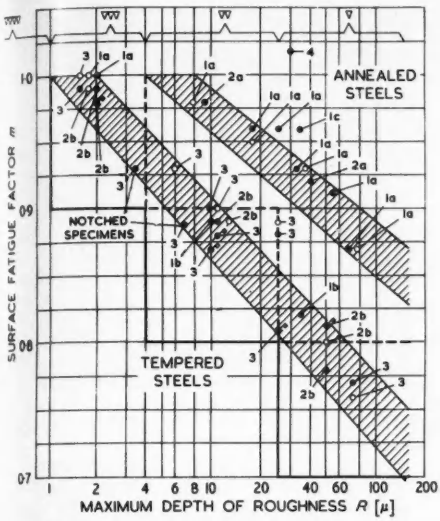


Fig. 5. **Surface fatigue factor m as a function of surface roughness R in push-pull (solid circles) and bending (open circles) fatigue tests, for various materials listed in Table I.**
Points marked with flags indicate specimens annealed in vacuum after machining.

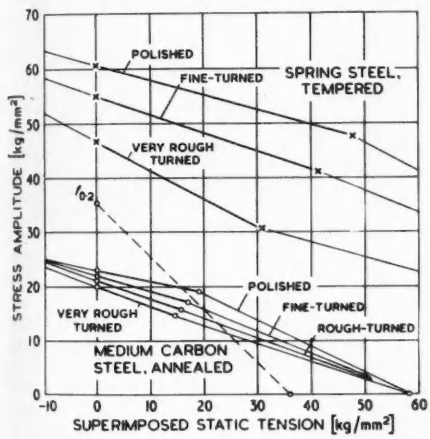


Fig. 6. **Influence of superimposed static tension on the push-pull fatigue strength of tempered spring steel and of annealed medium carbon steel, with different degrees of surface roughness.**

fracture in fatigue, but merely suffer permanent deformation and, since deformation depends on yield strength, which is virtually independent of surface roughness, the influence of surface roughness on fatigue strength must therefore decrease with superimposed static compression.

No tests were carried out under actual static compression, so that nothing can be said regarding the continuation of the lines in the compressive region. Similarly, no tests were made in the region of high static tension, the curves in Fig. 6 being simply extrapolated to the point of static tensile strength on the abscissa. The practical useful region of the diagram is limited in any case by the (dotted) line of yield strength. It would appear from the literature that sensitivity to surface roughness in the fatigue testing of notched or drilled specimens increases with superimposed static tension, the increase

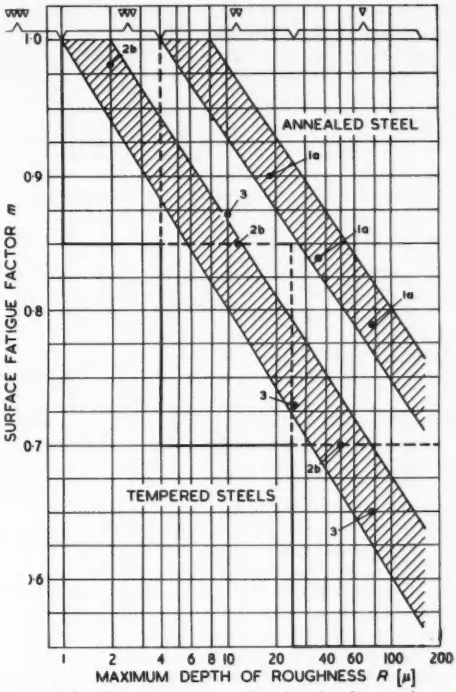


Fig. 7. **Surface fatigue factor m as a function of surface roughness R in fatigue tests in repeated tension of three annealed and tempered steels listed in Table I.**

being small for fatigue in torsion and appreciable in bending and push-pull.[5] The micro-notches of a machined surface will act similarly, the point of highest stress at the root of the notch reaching tensile yield for a lower value of the applied alternating stress. The effect increases with static tension and will be more pronounced on the rougher surface.

(3) Even the few results given in Table II indicate the reduced influence of a rough surface on torsional fatigue. The principal directions are at 45 deg. to the machining grooves, so that these do not exert their full effect in fatigue. According to Ludwik[6], the relationship

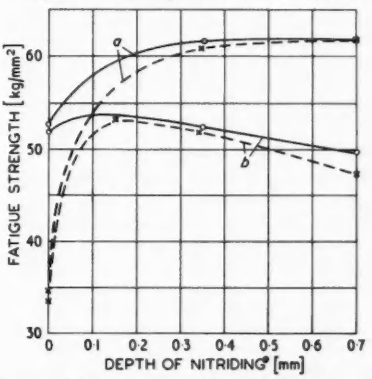


Fig. 8. **Tests on nitriding steel (material No. 5 in Table I) for (curve a) bending fatigue (shape of specimen as in Fig. 2), and (curve b) push-pull fatigue (specimen as in Fig. 1).**
Solid lines : Polished specimen, with $R < 1\mu$.
Dotted lines : Rough-machined specimen, with $R \approx 50\mu$.

between the torsional fatigue limit q_0 and the tensile fatigue limit f_0 of plain polished specimens, i.e., $q_0 = 0{\cdot}57\, f_0$ (Mises Criterion), can also be applied to notched specimens in the form

$$1 - \frac{q}{q_0} = 0{\cdot}57\left(1 - \frac{f}{f_0}\right)$$

where q and f are the limiting shear and direct stresses in notch fatigue. As far as can be seen from the tests discussed in this article, this rule is also applicable to the effect of rough surfaces.

Evaluation for Design

For each machining process, a certain maximum depth of roughness R can be specified, e.g., 1μ for polishing, lapping, honing, etc.; 4μ for grinding; 25μ for fine machining and fine turning; and 160μ for roughing.

The intervals thus assigned to the various machining processes are marked at the top of Figs. 5 and 7, in which the surface fatigue factor m is unity for polished specimens and decreases linearly with increasing surface roughness. If the line is replaced by constant steps for each machining interval, these steps must be so chosen that the full scatter of the test results still remains on the safe side. In Fig. 5, this leads to the (solid) stepped line for tempered steels, and to the (dotted) stepped line for annealed steels, in push-pull and fully reversing bending tests. For example, suppose that a tempered steel has a bending fatigue strength of 45 kg/mm² for a plain polished specimen ; then, a component with a fine-turned surface can be expected to have a bending fatigue strength of $45m = 45 \times 0{\cdot}8 = 36$ kg/mm².

The smaller influence of roughness on torsional fatigue, as shown by Ludwik's tests on notched specimens, can be accounted for by a smaller percentage decrease of the surface fatigue factor m at each step, and the greater influence of superimposed static tension by a higher factor m. From the test results obtained in this investigation it appears that the decrease $(1 - m)$ for torsional fatigue may be taken as half that of bending or push-pull fatigue and for tension as 1½ times that of bending. Fig. 7 shows that the values thus obtained are still safe. Accordingly, a ground component of tempered steel, with $R = 1$ to 4μ, will have a factor m of 0·9 in push-pull and bending fatigue, 0·85 in tension, and 0·95 in torsion. An annealed steel will have the same factors for a surface roughness R of 4 to 25μ. A surface finish finer than $R = 1\mu$ on tempered steels, or 4 to 6μ on annealed steels, does not further improve the fatigue strength. It can be expected that cast steel and cast iron are sensitive only to still greater degrees of roughness. The intervals chosen here may be subdivided still further, but a scheme of the type adopted seems to be the simplest for practical design calculations.

Surface Treatment after Machining

If the mechanical strength of the surface layers is improved or if compressive residual stresses are induced, the fatigue limit is raised and is made less dependent on surface roughness. Even very thin nitrided layers almost completely compensate the drop in fatigue strength due to surface roughness (Fig. 8). Consequently, from the point of view of fatigue alone, nitrided surfaces need not be fine-machined, the reason obviously being that the fatigue fracture starts below the surface (Figs. 9 and 10). In fully reversing bending, the origin of the crack is at the point of transition to the higher hardness of the nitrided layer. In push-pull, it is nearer to the axis. It is known that the improvement in fatigue strength caused

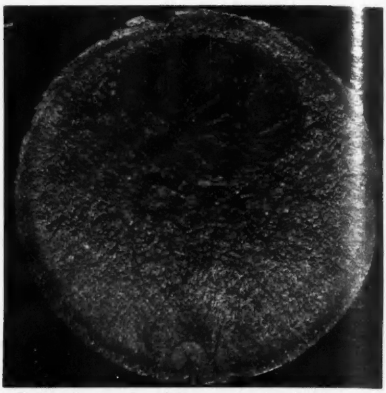


Fig. 9. **Fatigue fracture in a fully reversing bending fatigue test on a specimen (material No. 5c in Table I) wi h a rough-machined surface.** Diameter of specimen, 7·50 mm ; maximum stress, 72·0 kg/mm² ; load applications to fracture, 310,000.

Fig. 10. **Fatigue fracture in a push-pull fatigue test on a specimen (material No. 5d in Table I) with a rough-machined surface.** Diameter of specimen, 5·00 mm ; maximum stress, 52·0 kg/mm² ; load applications to fracture, 2,650,000.

by nitriding depends very considerably on stress distribution and gradient. The decrease in push-pull fatigue strength with increasing depth of nitriding, as indicated in Fig. 8, is due to the unfavourable residual tensile stresses produced in the core by the surface treatment.

From the literature on tests with notched specimens, it has been established that other surface-hardening treatments (e.g., case-, induction-, and flame-hardening) lead to similar results. Cold-forging, cold-rolling, and shot-peening deform the surface layers plastically, work-harden them, and induce residual compressive stresses. Different conditions of treatment lead to widely varying and only very conditionally comparable fatigue-strength results.[7] The influence of surface roughness is again strongly reduced or entirely eliminated by these mechanical surface treatments.

REFERENCES

(1) A. Schaal : *Zeitschr. Metallkunde*, Vol. 40, 1949, pp. 417–427.
(2) W. Leyensetter : *Stahl u. Eisen*, Vol. 72, 1952, pp. 1139–1144.
(3) H. Wiegand : " Oberfläche und Dauerfestigkeit " ; Berlin, 1941.
(4) A. Q. Mowbray: *Proc. Soc. Exp. Stress Analysis*, Vol. 10, 1952, pp. 153–166.
(5) M. Hempel : *Arch Eisenhüttenw.*, Vol. 12, 1939, pp. 433–444.
(6) P. Ludwik. *Zeitschr. Metallkunde*, Vol. 22, 1930, pp. 474–478.
(7) R. I. Love : " Properties of Metallic Surfaces " ; Inst. of Metals, London, 1953, pp. 161–196.
E. R. Gadd : *Jour. R. Aeronaut. Soc.*, Vol. 57, 1953, pp. 565–580.

Note :—The original article contains 54 references.

The Effects of Various Additions on the Properties of Copper-Alloy Springs

By M. KAWASAKI and O. IZUMI. (From *The Science Reports of the Research Institutes, Tôhoku University*, Series A, Vol. 8, No. 6, 1956, pp. 484–501, 24 illustrations.)

IT is well known that nickel silver, phosphor bronze, and beryllium bronze are excellent spring materials in many applications. However, as these alloys contain nickel, tin, or beryllium, they present some difficulties in formability. Brass is also a commonly used spring material but, despite the fact that it has a number of comparatively favourable characteristics, such as ease of manufacture and low cost, it also has several disadvantages. Thus, for instance, although it contains about 40% zinc and is heavily cold-rolled (to a reduction of approximately 75%), its spring properties are inferior to those of the alloys mentioned above, and its formability is impaired after the heavy cold-working. Furthermore, the values of residual deflection in static spring tests on brass are greater than those of the other copper alloys, even though final annealing may be effected at the optimum temperature of 400°C. Finally, its most unfavourable characteristic is that of deterioration of spring properties with time, even with optimum treatment for spring properties, i.e., cold-working and low-temperature annealing, and this tendency becomes more pronounced with increasing zinc content. Low heat resistivity and low contact conductivity may also be considered as defects. The object of the present investigation, therefore, was the improvement of the spring properties of brass and other copper alloys by the addition of various elements.

EXPERIMENTAL PROCEDURES AND RESULTS

Tests were carried out on a series of brasses (60% Cu, 40% Zn) containing additions of iron, aluminium, manganese, nickel, cadmium, and tin. These elements were added so as to show the same ratio of alpha and beta phases on the basis of a 60/40 brass containing 1% Fe. In addition, the Cu-Mn-Ni and Cu-Fe alloys were examined, the Cu-Mn-Ni alloys containing 9·6% Mn and 11·6% Ni, and 14·6% Mn and 19·0% Ni, and the Cu-Fe alloys about 4% Fe, i.e., the limiting amount in the range of solid solution. All these alloys were melted in a coke furnace, with the exception of the Cu-Mn-Ni alloys, which were melted in a high-frequency electric furnace. The amount of each charge was about 2·5 kg, cast in an iron mould, 20 × 90 × 150 mm. Ingots were homogenized at 700 to 800°C for 24 hr after scalping, and then hot-rolled at 700°C.

The series of brasses was cold-rolled from 5 to 2 mm in thickness, with intermediate annealing at 600°C for 30 min, and finally cold-rolled to 0·5 mm, i.e., a 75% reduction, after final annealing at 400°C for 1 hr.

The Cu-Mn-Ni alloys were hot-rolled to 2 mm and divided into two groups, i.e., furnace-cooled, and water-quenched after annealing at 700°C for 1 hr, both groups being then cold-rolled to 0·5 mm (75% reduction).

The Cu-Fe alloys were hot-rolled to 4 mm thickness and also divided into two groups, i.e., (1) furnace-cooled after being held at 800°C for 1 hr and then cold-rolled to 0·5 mm, with an intermediate low-temperature anneal at 250°C for 30 min, the total reduction being 87·5%, and (2) tempered at 550°C for 1 hr after a water-quench at 950°C, and then cold-rolled to 0·5 mm.

Spring tests were carried out in a spring fatigue-testing machine in such a way that spring properties could be compared by measuring the residual deflections (permanent set) δ caused by repeated bending applied to the fixed end of a cantilever, 50 mm in length. Hence, elastic limits could be determined by measuring the maximum surface stress at which the residual deflection δ was exactly 0·1 mm after 50 cycles. Bending tests of 2000 cycles under loads near the elastic limit were carried out and the residual deflection observed, the frequency of stress application being about 300 cycles per minute. In addition, Vickers hardness was measured under a load of 10 kg.

Special Brasses:—

Insofar as the results of tests on the series of brasses with various additions were concerned, those obtained with the following specimens are representative:— Specimen *A*: 42·2% Zn, 0·28% Al; specimen *B*: 42·2% Zn; specimen *C*: 40·6% Zn, 0·60% Sn; specimen *D*: 40·9% Zn, 1·56% Cd; specimen *E*: 40·9% Zn, 1·56% Ni; specimen *F*: 42·1% Zn, 0·86% Fe; and specimen *G*: 41·0% Zn, 0·98% Mn.

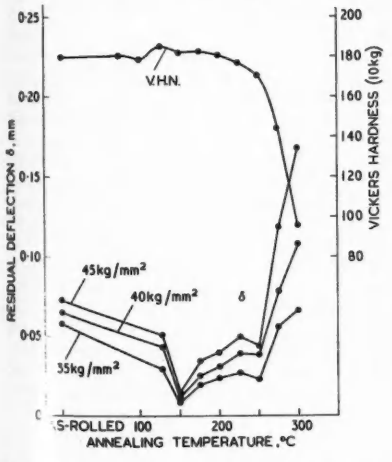


Fig. 1. (left) Spring and hardness tests on a specimen of brass containing 40·6% Zn, 0·60% Sn.

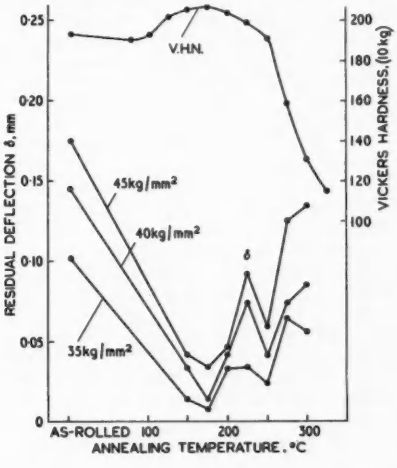


Fig. 2. (right) Spring and hardness tests on a specimen of brass containing 42·1% Zn, 0·86% Fe.

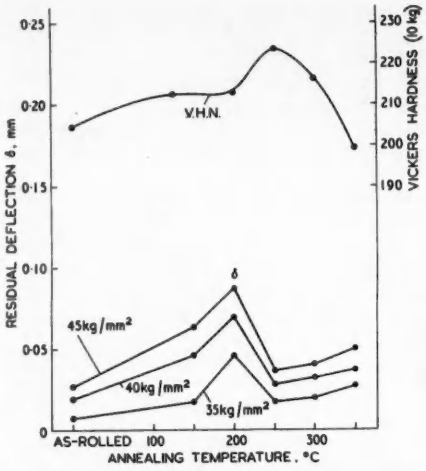


Fig. 3. (left) Spring and hardness tests on a furnace-cooled Cu-Mn-Ni alloy containing 9·6% Mn, 11·6% Ni.

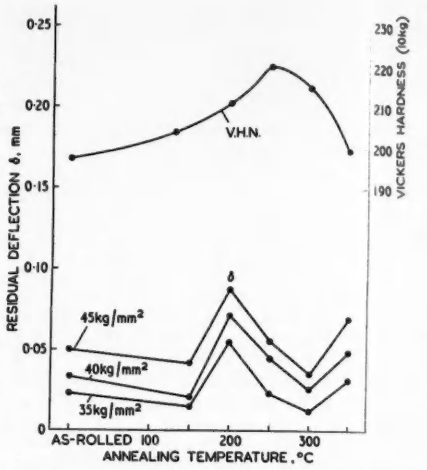


Fig. 4. (right) Spring and hardness tests on a water-quenched Cu-Mn-Ni alloy containing 9·6% Mn, 11·6% Ni.

In the as-rolled condition, specimen *C* showed comparatively superior properties, followed by specimens *D*, *E*, and *G*. The results for specimen *C* are given in Fig. 1, which shows, in addition to changes in Vickers hardness caused by low-temperature annealing for 1 hr, curves of residual deflection δ at maximum surface stresses of 35, 40, and 45 kg/mm² respectively. In the as-rolled condition, specimens *A*, *B*, and *F* gave the least satisfactory results.

The minimum values of deflection and their corresponding temperatures varied slightly with different alloys, but their differences under different loads for each temperature were very small. Although it is true that the smaller are these values, the better are the spring properties (as noted, for instance, with specimens *G*, *C*, and *B*), it would be more favourable if there were a wider range of temperatures at which deflections were minimum; otherwise, difficulties might arise in practice during heat treatment. Consequently, from the results obtained, it was considered that specimens *F*, *G*, *A*, *C*, and *D*, in that order, would be better than specimens *B* or *E*. Furthermore, from the point of view of heat resistivity, specimens *F*, *G*, *A*, and *C* could be considered as better spring materials than ordinary brass, i.e., specimen *B*. At room temperature, specimens *F* and *A* gave smaller values of specific electrical resistivity than the other specimens, with the exception of *B*, and this might be significant in electrical applications. The results obtained for specimen *F* are shown in Fig. 2.

Cu-Mn-Ni Alloys:—

The results of tests on the furnace-cooled Cu-Mn-Ni alloy containing 9·6% Mn and 11·6% Ni are shown in Fig. 3, and on the same water-quenched alloy in Fig. 4. From metallographic considerations, some improvements in the mechanical properties of Cu-Mn-Ni alloys can be expected from quenching and tempering, as a result of their pseudo-binary system. This was confirmed by the tests of spring properties, especially from the point of view of heat resistivity, for this alloy, with its comparatively low manganese and nickel content. The results of these tests showed that this alloy was satisfactory, when annealed at 350°C, and that the deflection due to various loads was comparatively stable. The alloy showed superior properties in the as-rolled condition, compared with the special brasses and other alloys tested, and its deflection increased temporarily at 200°C, so that it resembled a type of quenched and tempered Cu-Be alloy. Consequently, the temperature most suitable for low-temperature annealing was considered as between 275 and 300°C, which, as shown in Figs. 3 and 4, is satisfactory from the point of view of hardness. With regard to furnace-cooling or water-quenching, the difference occasioned by these two types of heat treatment appeared to be negligible.

In the case of the Cu-Mn-Ni alloy containing 14·6% Mn and 19·0% Ni, the residual deflection δ was found to be similar to that of an alloy of the solid-solution type, and the minimum points of deflection were observed at 250°C for the water-quenched alloy and 150 and 300°C for the furnace-cooled alloy. The furnace-cooled alloy gave comparatively high hardness values and a wider and more stable temperature range of small deflections than the water-cooled alloy, possibly caused by the difference in heat treatment. The improvements noted with these alloys were not as great as had been expected, perhaps owing to the fact that their composition is not truly that of a pseudo-binary system. Nevertheless, they can be considered to be satisfactory heat-resistant materials.

Cu-Fe Alloys:—

The results of tests on furnace-cooled and water-quenched Cu-Fe alloys containing 4·21% Fe are shown in Fig. 5. Hardness was low, compared with the other alloys tested, and, as expected, the absolute values of residual deflection were considerably greater, though they might possibly be improved by increasing the iron content. It is interesting to note that the furnace-cooled alloy showed a minimum deflection of about 0·15 mm at 200°C. On the other hand, although the water-quenched alloy showed a minimum deflection at 150°C, its value was higher than that of the furnace-cooled alloy at 200°C. Between 200 and 350°C, the furnace-cooled alloy was superior to the water-quenched alloy, but the latter, above this range, was more stable than the furnace-cooled alloy up to 600°C. Below 350°C the behaviour of both alloys was remarkably different from that observed with conventional heat-treatable alloys, particularly with regard to the precipitation of iron from the supersaturated solution.

In general, it is believed that the Cu-Fe alloys ex-

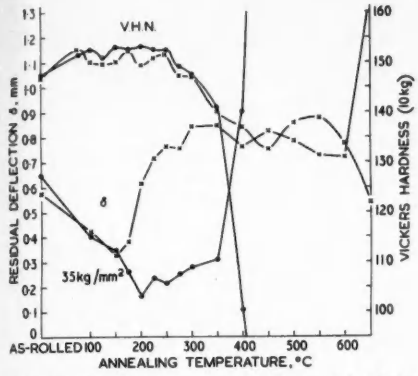


Fig. 5. Spring and hardness tests on a Cu-Fe alloy containing 4·21% Fe, showing results for a furnace-cooled specimen (solid lines) and a water-quenched specimen (dotted lines).

hibited good spring properties and can be considered as satisfactory spring materials, provided that heat treatment is carried out correctly and that the iron content is higher than 4%.

Additional Tests and Results

The results of the previous tests established that the addition of iron, manganese, tin, and aluminium improved the spring properties of 60/40 brass. It was therefore considered desirable to institute further tests on alloys containing various percentages of iron, manganese, tin, and manganese and tin combined, and to include some investigations into their formability.

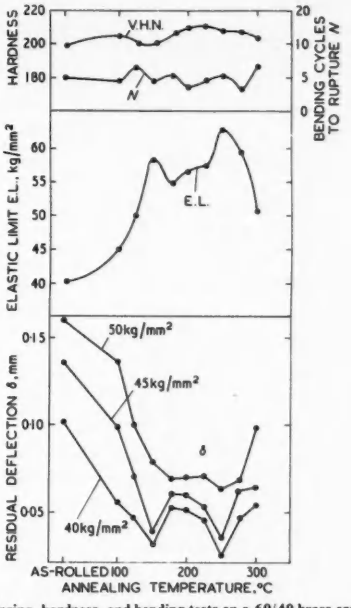


Fig. 6. Spring, hardness, and bending tests on a 60/40 brass containing 1·2% Fe.

In these tests, each alloy was cast and rolled to a

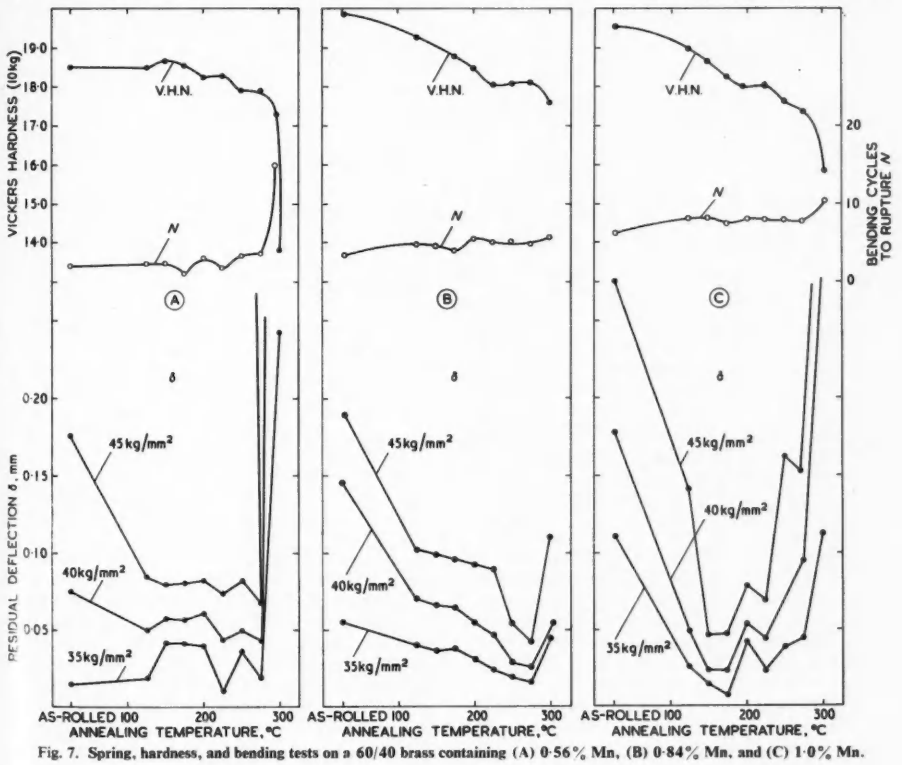


Fig. 7. Spring, hardness, and bending tests on a 60/40 brass containing (A) 0·56% Mn, (B) 0·84% Mn, and (C) 1·0% Mn.

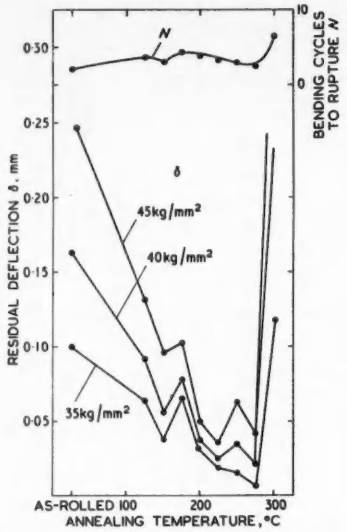
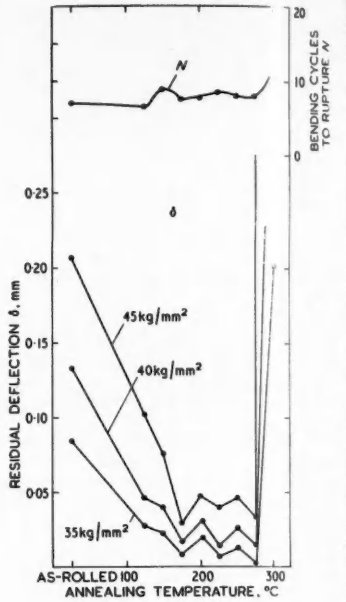


Fig. 8. (left) **Spring and bending tests on a 60/40 brass containing 0·99% Sn.**

Fig. 9. (right) **Spring and bending tests on a 60/40 brass containing 0·53% Sn, 0·69% Mn.**



thickness of 0·5 mm, and all specimens were cut from the rolled sheet in the transverse rolling direction. After cutting, specimens were machined to a standard size of 0·5 × 10 × 130 mm. Low-temperature annealing was effected between 125 and 300°C for 1 hr.

The alloys of brass and iron were first hot-rolled from 22 mm to 5 mm, and then cold-rolled to 0·5 mm, with an intermediate anneal at 550°C. The final annealing temperature was 450°C, and final reductions were 30%, 50%, and 70%. The alloys of brass and manganese and tin were hot-rolled from 26 mm to 13 mm, and then cold-rolled to 0·5 mm, with an intermediate anneal at 500°C. The final annealing temperature was 600°C, and final reductions were 50% and 70%.

Measurement of spring properties was carried out in the same way as previously. Formability was estimated by measuring the number of bending cycles through 180 deg. to rupture, the bending radius being 5 mm. In addition, Vickers hardness was measured as before.

Brass Containing Iron:—

The result of measurements of elastic limit, residual deflection, hardness, and bending cycles to rupture of a 60/40 brass containing 1·2% Fe, with a reduction of 50%, are shown in Fig. 6. Similar tests were carried out on 60/40 brass containing 1·6% and 2·0% Fe, and, in all cases, it was found that, with the as-rolled specimens, iron content appeared to have but little effect on elastic limit. Low-temperature annealing, however, was found to provide a remarkable improvement, the elastic limit being about 63 kg/mm² for the specimen containing 1·2% Fe, 64 kg/mm² for the 1·6% Fe specimen, and nearly 65 kg/mm² for the 2·0% Fe specimen, with reductions of both 50 and 70%. Even with a reduction of 30%, all these specimens gave values of elastic limit of about 55 kg/mm², so that they would definitely appear to be of practical use as spring materials. It should be noted, however, that values of elastic limit were temporarily lowered between 175 and 200°C, so that heat treatment at each temperature requires care.

From the bending tests, it was established that bending properties deteriorated very considerably when the rolling reduction was increased from 50 to 70%. It is therefore considered that the critical rolling reduction of this alloy is about 40%. The effect of iron content on bending properties was, however, not so noteworthy. In general, then, it is concluded that a 60/40 brass containing from 1 to 2% Fe is likely to be of practical use as a spring material, provided that, as mentioned, the rolling reduction does not exceed about 40%.

Brass Containing Manganese:—

The results of tests on a 60/40 brass containing three different amounts of manganese, with a reduction of 50%, are shown in Fig. 7. In the as-rolled condition, it would appear that an increase in manganese content causes deterioration of spring properties. After low-temperature annealing, however, the properties of these alloys were superior to those of ordinary brass over a considerably wider range of annealing temperatures. The temperatures at which minimum deflections were noted varied with manganese content. Thus, in the case of the alloys containing 0·56 and 0·84% Mn, minimum deflection values were registered at comparatively high temperatures, whereas, in the alloy containing 1·0% Mn, the minimum deflection value was registered at a considerably lower temperature. It was also found that, with materials cold-rolled to a reduction of 70%, spring properties were superior to those obtained with a 50% reduction. The maximum value of the elastic limit of these alloys is estimated to be about 70 kg/mm², i.e., superior to that of the alloy containing iron, with its maximum value of about 65 kg/mm². On the other hand, although the bending properties of the alloys containing manganese were comparatively stable throughout the temperature range up to 275°C, the absolute number of bending cycles was less than 10, even with the rolling reduction of 50%. This disadvantage would become even more pronounced with higher rolling reductions, so that, for practical purposes, a reduction of 50% may well be considered the limit for cold-rolling.

(Concluded on page 120)

The Thermodynamics of Water-Cooled Copper Tubes used in Induction Heating

By H. GEISEL. (From *Elektrotechnik und Maschinenbau*, Vol. 73, No. 24, December 15, 1956, pp. 553–557. 2 illustrations.)

THE coils employed in the induction heating of steel and non-ferrous metals are generally made of copper tubing, preferably of rectangular cross-section. Water cooling is necessary because of the high current densities (100 A/mm² or higher) occurring in the conductive cross-section and because of the single-layer arrangement of the coil, required to obtain good efficiency. It is only very rarely that air-cooled solid or braided-wire types of coils provided with special high-temperature insulation can be used, e.g., in the induction heating of boiler walls in the chemical industry.

In most cases, the diameter and length of the copper tubing are to a considerable extent determined by the coil dimensions and the voltage rating of the generator or the secondary voltage of the intermediate transformer, if used. The amount of power dissipated as heat is therefore also predetermined. This heat, which has to be carried away by the cooling water, consists of the energy due to RI^2 losses, and also of some of the heat radiated back to the inductor coils by the heated material.

To avoid breaking away of the flow from the inner wall of the copper tube owing to vapour formation, the cooling-water outlet temperature should be, as far as possible, less than 70°C. Thus, if the inlet temperature is about 20°C, the temperature rise $\Delta\theta$ of the water should in no case be higher than 50°C. In the design stage, therefore, the problem to be considered is whether the flow of cooling water, with a specified head, is sufficient to prevent an outlet temperature of more than 70°C. If the quantity of water flowing per second is too small, it will be necessary to subdivide the coil into two or three flow systems. The total flow volume V [litres/min] required can easily be determined from the power P [kW] dissipated in the form of heat, by means of the equation

$$V = P/(0{\cdot}07\Delta\theta) \quad .. \quad .. \quad .. \quad (1)$$

In general, increasing the pressure head is not very successful, because flow volume increases as the square root of head, so that, when supply pressure is doubled, flow is increased by only about 40%.

CALCULATION OF HEAT GENERATED BY CURRENT

The heat developed by the flow of current can be determined by means of Joule's law as

$$P' = I^2R/10^3 \quad [\text{kW}] \quad .. \quad .. \quad (2)$$

where I = coil current [A], calculated from the effective power, coil voltage, and power factor, and R = effective resistance [ohms] of the copper tube to the passage of alternating current.

With regard to the value of the a.c. resistance R, it may be noted that the current through the coil will select its path in such a way that the magnetic energy of the coil will be a minimum, i.e., so that the coil inductance will have a minimum value. This means that most of the current will flow in those portions of the tubing which are nearest to the coil axis[1]; in this way, the current encloses the smallest possible surface area. The "penetration depth" δ of the current in the wall of the copper tubing can be calculated from

$$\delta = 503/\sqrt{\chi\mu f} \quad [\text{mm}] \quad .. \quad (3)$$

where χ = electrical conductivity of the copper material [m/ohm-mm²], μ = relative permeability, and f = frequency [cps.]. For copper, χ = 57 m/ohm-mm² at 20°C (50 at 50°C). Thus, the penetration depth δ decreases hyperbolically with increasing frequencies, ranging from δ = 9·4 mm at 50 cps to 0·67 mm at 10,000 cps, these values being at a temperature of 20°C. The values of δ at 50°C are from 5 to 10% greater.

Usually, the wall thickness h of the copper tube is chosen so that it will be at least equal to the penetration depth δ. If h is much greater than δ, the current-density distribution as a function of depth x (i.e., the radial distance inside the tube wall from the internal surface of the coil) decreases in accordance with an exponential law; where h is of the same order as δ, the relation is more complicated.[2, 3] Representative curves are shown in Fig. 1.

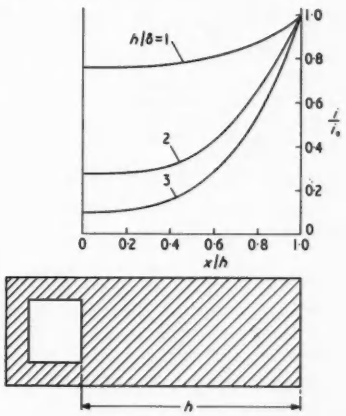


Fig. 1. Distribution of current density in the wall of a copper heating coil, for various values of wall thickness h and penetration depth δ.

For calculating the effective resistance R, it can be assumed that current-density i has a constant value i_0 from the boundary of the coil inner surface to a depth δ inside the tube wall, this value being that of the current density at the boundary.[4] At depths greater than δ, it is assumed that the current density is zero. If b = width of copper tube (measured perpendicular to δ), the cross-section a which carries the current is $a = b\delta$ [mm²], and the effective a.c. resistance of the copper tube of total developed length l metres is therefore

$$R = l/(\chi b\delta) \quad .. \quad .. \quad .. \quad (4)$$

However, this equation gives reasonably accurate values only when the wall thickness h of the tube is much larger than δ, and when the distance between the individual turns of the coil is negligibly small. For greater accuracy, it is advisable to use the correction function Y plotted against $2h/\delta$, given in Fig. 2.

With the Y-value corresponding to the value of $2h/\delta$ under consideration, and a space factor s, defined as

$$s = b/Z \quad .. \quad .. \quad .. \quad (5)$$

where Z = pitch of the coil, it is convenient to introduce

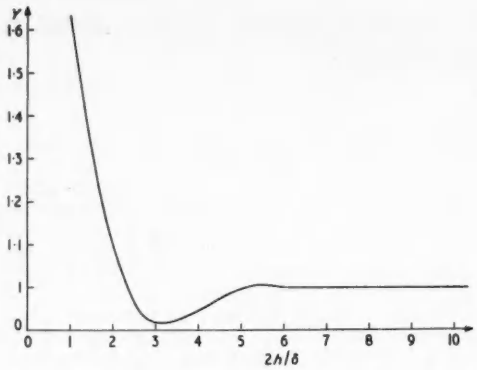


Fig. 2. **Correction function Y for the calculation of the effective a.c. resistance of heating coils**

an "equivalent width" b' for the copper tubing, and this is evaluated as

$$b' = (b/Y)\sqrt{s} \quad .. \quad .. \quad .. \quad (6)$$

The effective resistance R is then obtained from

$$R = l/(\chi b'\delta) \quad .. \quad .. \quad .. \quad (7)$$

and this value is used in eq. (2) for the evaluation of power dissipation due to the flow of current.

It may be noted that the function Y plotted in Fig. 2 represents the expression

$$Y = [\sinh(2h/\delta) + \sin(2h/\delta)]/[\cosh(2h/\delta) - \cos(2h/\delta)]$$

obtained from theoretical considerations, and has a minimum value at $h = \pi\delta/2$.

Additional Heat due to Radiation from the Heated Material

The calculation of the additional quantity of heat due to radiation from the heated material is comparatively easy, if the coating of the coil (e.g., insulating varnish or vitreous enamel) is relatively thin, or if the gap between the surface of the heated material and the internal surface of the coating is relatively large. With thin coatings the additional heat capacity is in most cases negligible, and with large gaps the coating temperature is usually so low that temperature differences between the inner and outer surfaces can be neglected. The heat P'' transferred by radiation from the heated material to the coating of the coil can be calculated by means of the Stefan-Boltzmann law as

$$P'' = CA_1[(T_1/100)^4 - (T_2/100)^4] \quad [\text{kW}] \quad .. \quad (8)$$

where A_1 = portion of surface area [cm²] of heated material enclosed by the heating coil, T_1 = temperature of heated material [°K], T_2 = temperature of coating [°K], and C is a constant, determined from

$$C = C_b \Big/ \left[\frac{1}{\varepsilon_1} + \frac{A_1}{A_2}\left(\frac{1}{\varepsilon_2} - 1\right)\right]$$

where C_b = black-body radiation constant = $5{\cdot}77 \times 10^{-7}$ kW/cm² °K⁴, ε_1 = emissivity of surface of heated material, ε_2 = emissivity of coating, and A_2 = surface area [cm²] of coating receiving radiation.

For purposes of estimation, it is convenient to make a table of values of $(T/100)^4$, corresponding to different temperatures t in °C. Such a table will show that the temperature T_2 of the coating can be neglected in eq. (8) if it is considerably lower than the temperature T_1 of the heated material. For instance, if $t_1 = 1200$°C and $t_2 = 400$°C, then $(T_2/100)^4 = 2055$ approximately, and $(T_1/100)^4 = 47{,}080$ approximately, so that $(T_2/100)^4$ is only about 4% of $(T_1/100)^4$, and is therefore negligible. In practice, it does not matter whether $t_2 = 400$°C or whether it is equal to room temperature. Furthermore, heat transfer through conduction and convection is much smaller than that due to radiation and may also be neglected.

For thick layers of coating material and for narrow gaps, the calculation becomes more complicated, but formulae are also available for such cases.[4]

Calculation of Water Pressure Required

The cooling water flowing through the comparatively narrow copper tube must have a head sufficient not only to provide the requisite dynamic pressure but also to overcome two main types of resistance, i.e., (1) resistance due to friction of the liquid on the tube walls, and (2) resistance due to fittings such as bends, tees, elbows, etc.

The total head p [kg/m²] required can be calculated from the relation

$$p = \gamma\,(w^2/2g)\;[1 + (\lambda l/d) + \Sigma\zeta] \quad .. \quad .. \quad (9)$$

where w = flow velocity [m/sec], g = acceleration due to gravity = 9·81 m/sec², γ = density of water = 1000 kg/m³, λ = coefficient of friction, l = total developed length of tubing [m], d = inner diameter of tube [m] (calculated from eq. (10)), and ζ = resistance factor for bends, etc.

The coefficient λ for smooth tubes depends only on the Reynolds number $\mathrm{Re} = wd/\nu$, where ν = kinematic viscosity [m²/sec].

For tubes of rectangular section of external dimensions h and b, and wall thickness s, the equivalent diameter can be evaluated as

$$d = 2(b - 2s)\,(h - 2s)/(b + h - 4s) \quad .. \quad (10)$$

For medium-frequency coils, flow velocities w between 1 and 5 m/sec and tube diameters d of the order of 5 mm can be regarded as usual values. For convenience, the calculation can be based on a mean water temperature of 40°C, corresponding to a ν-value of $0{\cdot}66 \times 10^{-6}$ m²/sec. Then, for instance, if $w = 3$ m/sec, the Reynolds number is $\mathrm{Re} \simeq 23{,}000$, so that the flow is definitely turbulent, the change from laminar to turbulent flow being at a Reynolds number of about 2300. For smooth tubes, the coefficient of friction λ can be evaluated by means of Blasius's equation, i.e.,

$$\lambda = 0{\cdot}316/\sqrt[4]{\mathrm{Re}} \quad .. \quad .. \quad .. \quad (11)$$

This equation is valid for Re-values up to 100,000. For $\mathrm{Re} = 23{,}000$, $\lambda = 0{\cdot}025$, which is in good agreement with results obtained in practice with straight copper tubes.

It is convenient to replace the expression in square-brackets in eq. (9) by a coefficient of "total equivalent resistance" λ', defined as

$$\lambda' = (d/l)[1 + (l\lambda/d) + \Sigma\zeta] \quad .. \quad .. \quad (12)$$

This λ'-value can be determined by measurements in tests on various coils, and the data thus obtained can serve as a basis for evaluations of similar coils. The expression for the total head simplifies, therefore, to

$$p = (w^2/2g)\gamma\lambda' l/d \quad .. \quad .. \quad .. \quad (13)$$

If V = flow volume [litres/sec] and A is the internal

cross-section, the relation between V and w (flow velocity) is $V = Aw$.

It is frequently permissible to neglect the power dissipation P'' in comparison with the RI^2-loss. The total power to be carried away is then $P = P'$. Now, Newton's equation is

$$P = V\gamma c\Delta\theta$$

where c is the specific heat of water, so that the dissipated power is

$$RI^2 = Aw\gamma c\Delta\theta$$

Taking account of eq. (7), the result is

$$w = I^2 l/(A\gamma c\chi b'\delta\Delta\theta) \quad .. \quad .. \quad (14)$$

Substitution of this expression in eq. (13) gives the required head p, i.e.,

$$p = \frac{I^3}{A^2 db'^2} \times \frac{\lambda'}{2g\gamma\chi^2 c^2\delta} \times \frac{I^4}{(\Delta\theta)^2} \quad .. \quad .. \quad (15)$$

This indicates that the required head is proportional to the fourth power of the current. As a first approximation, the first two fractions on the right-hand side of this equation can be regarded as constants, so that, for a given coil and for a specified frequency, the formula becomes

$$p = \text{const.} \times I^4/(\Delta\theta)^2 \quad .. \quad .. \quad (16)$$

For constant $\Delta\theta$, p is proportional to I^4 ; however, if, on the other hand, the working pressure p is kept constant, i.e., the flow volume is constant, then the temperature rise $\Delta\theta$ will be proportional to the square of the current.

From $V = Aw$ and eq. (13), it follows that

$$V^2 = (A^2 d/l) \times (2g/\gamma\lambda') \times p \quad .. \quad .. \quad (17)$$

$$\text{or} \quad V = \text{const.} \times \sqrt{p} \quad .. \quad .. \quad .. \quad (17')$$

This confirms the fact, previously mentioned, that the flow volume is increased only to a limited extent by using a higher pressure. A more effective solution is to increase the number of cooling circuits. If the coil is subdivided into two cooling circuits, then from eq. (17) it is seen that, since l is halved, V will be 1·4 times greater in each of the two circuits, so that the total increase in flow volume will be 2·8 times for the entire coil. With three separate circuits, the flow volume will be 5·2 times greater than for the coil with a single cooling system.

REFERENCES

(1) ROHMANN : " Elektrische Schwingungen " ; Sammlung Göschen No. 751, p. 35.

(2) LANGER : *Elektrotech. Obzor*, Vol. 42, No. 2, 1953, pp. 124–132.

(3) GEISEL : " Die Wärmetechnik des wassergekühlten Kupferrohres für Induktionsspulen " ; to be published.

(4) GEISEL : *Elektrowärme-Technik*, Vol. 6, No. 5/6, 1955, pp. 93–101.

U.S.A.

The Prevention of Vibration in Airborne Equipment

By S. P. MERCURIO, JR. and M. BELBY.

(From *Electronics*, Vol. 30, No. 1, January 1957, pp. 166–168, 7 illustrations.)

ONE of the most important considerations for airborne electronic equipment is the design of the mechanical chassis or supporting structure, which must be light in weight and of minimum size, yet able to maintain good mechanical strength. A good design should have a centre of gravity as close to the mounting surface as possible, to help reduce vibration amplification caused by coupling modes of vibration.

The chassis must be rigid, to maintain the natural frequencies of vibration above the testing frequency range, as resonant points subject the structure to high repeated loadings. Supporting members can be made rigid by increasing thickness, flanging the ends, changing the geometry of the structure, or by ribbing the surfaces. The use of gussets and the proper location of stiffening members also aid in reducing flexibility.

SELECTION OF COMPONENTS

Capacitors should be mounted to prevent relative motion between the leads and body. As an example, the use of 0·02-μF disc-type capacitors in one application resulted in broken leads during vibration. By the nature of its design, as shown in Fig. 1a, this capacitor caused a cantilever action. By changing the leads so that they were mounted axially, as in Fig. 1b, the cantilever effect was removed and the large relative motion existing during vibration was eliminated.

Transformers with mounting studs attached directly to the iron core are generally preferable. Studs mounted to a relatively weak housing can be pulled away by high vibration forces. If the mounting bolts are secured to the core, the large internal forces are removed from the housing.

" Ruggedized " meters are desirable to withstand vibration forces. The use of rubber grommets at the meter mounting studs will result in a low resonant frequency of the meter. Care should be taken to attach leads to the terminals with sufficient slack, to avoid wire breakage.

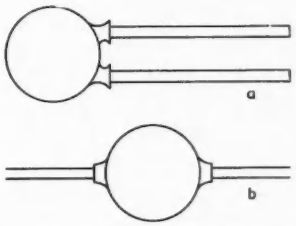


Fig. 1. Disc capacitor with (a) side mounting, and (b) axial mounting.

Large resistors mounted in ferrule clips should have spring locks, to ensure stability during vibration.

Wire breakage creates a major problem in design. When the component is mounted so that motion can take place because of isolation, sufficient wire slack should be provided. However, if the component is mounted solidly, so that motion cannot occur, leads should not have slack.

Excessive heating of wire during soldering should be avoided, as heat causes brittleness and produces low fatigue life.

CRYSTALS AND TUBES

Crystals have been mechanically redesigned to meet vibration requirements. For example, crystals in the

range of 244 to 428 kcs were selected at random and subjected to a vibration cycle of 5 to 500 cps at 2*g* maximum. The exterior crystal cans were removed, to enable the internal parts to be examined under vibration with a stroboscope. All crystals had severe resonant points. The lower-rated crystals experienced mechanical failure at the joining point of the crystal quartz leads and the supporting wire mounting. The failures were remedied by increasing the wire size, to provide greater support, and by eliminating several sharp bends. The ruggedized crystals had no resonant point within the 500-cps range.

Ruggedized tubes are being made which are capable of meeting higher vibration requirements. However, it is of little value to ruggedize a tube based on general vibration requirements, if the vibration conditions are not controlled in the structure. A tube may be designed for a maximum excursion of 0·010 in. at from 5 to 500 cps. If this tube is placed on a flexible member, the resulting excursion at resonance may be from two to four times as great.

Tube failure seldom occurs because the tube is inadequate. If ruggedized tubes are used with a good choice of tube location, a firm clamping system, and a good chassis and supporting structure, failures can be reduced sharply.

Fastening Devices

Components and sub-assemblies must be made accessible for ease of repair and maintenance, and must be firmly attached, to prevent imposing any great amplification of vibration forces.

Proper fasteners must be selected to obtain maximum use. Where sub-assemblies are attached permanently and removal is not a design requirement, rivets are useful. Rivets fastened by machine provide a more uniform tension than screws or bolts fastened by an individual assembler.

Where assemblies or components are to be mounted so that they may be removed, screws are often used. Lock washers should always be used in conjunction with screws. The split-ring lock washer, in particular, has been found to be satisfactory, because impact loading during vibration does not cause the adjacent soft metal, such as aluminium, to deform the washer.

The use of quick-disconnectors has the advantage of rapid removal and replacement, but care must be taken to ensure that the unit does not become overloaded by the use of improper disconnectors.

It is advisable to use ductile materials, when possible. When design demands the use of brittle materials, proper isolation should be provided, to prevent failures under impact loadings.

Vibration-Evaluation Testing

There are several points to be considered when conducting vibration-evaluation tests on airborne equipment. Testing facilities should be checked, to determine their accuracy. This includes checking the level of the vibration machines and resonance in the supporting table, and calibrating the velocity pick-ups, accelerometers, and other testing meters.

Fixtures used to mount the equipment should have a centre of gravity coinciding with the centre line of the table; otherwise, the equipment mounted on the fixture may be subjected to additional forces beyond the original test requirements, and invalid data will result. Weight added underneath the fixture brings the centre of gravity of the supporting fixture and mounted unit in line with the centre-line of the table. Thick aluminium plates are useful in making fixtures, since aluminium has a great relative damping capacity and little elasticity.

Before making a vibration test, each unit should be inspected for electrical and mechanical accuracy, and critical components should be tested to determine their ability to withstand vibration requirements. Wiring is then attached to the unit under test, and the vibration machine set up for initial vibration conditions. Vibration amplitude is checked by a vibrometer as the test proceeds.

Initial vibration of the assembly should be made at a reduced amplitude, to locate critical resonance points. From this test the transmissibility ratio of the equipment can be determined. In many cases, owing to damping in the system, these resonance points may not be objectionable. However, if the transmissibility is excessive, corrective action must be taken. Usually, supporting members are made more rigid by ribbing the surfaces, flanging the members, or increasing thickness so that unwanted resonance is above the test frequency range.

A monitoring device which will define the satisfactory electrical operation of the equipment is required. If at all possible, this device should encompass the complete electrical function on one indicator, such as an oscilloscope.

Recording instruments should be used, if adaptable to the particular test. It is also necessary to observe the equipment being tested for any mechanical failures, which may show up in a number of ways. A slight buzzing or an abrupt change in the magnitude or quality of the vibration noise generated by the equipment during testing is a common example of failure symptoms.

The Effects of Various Additions on the Properties of Copper-Alloy Springs

(*Concluded from page 116*)

Brass Containing Tin:—

The results of tests on a 60/40 brass containing 0·99% tin, with a reduction of 50%, are shown in Fig. 8. Although other tests on brass containing 0·53 and 0·77% tin indicated that spring properties deteriorate with decreasing tin content, the differences were not particularly pronounced. As in the case of the alloys containing manganese, the spring properties of the brass/tin alloys cold-rolled to a reduction of 70% were superior to those with a 50% reduction, and the annealing temperature at which a minimum deflection was noted was lower with the 70% reduction than with the 50% reduction. As expected, the bending properties of these alloys were comparatively inferior to those of the alloys containing manganese. However, the elastic limit of the 70% cold-rolled specimens was estimated to be about 75 kg/mm², i.e., higher than [illegible] or the alloys containing manganese.

Brass Containing Manganese and Tin:—

Tests were carried out on a 60/40 brass containing 0·31% Sn and 0·14% Mn, and 0·53% Sn and 0·69% Mn, the results of tests on the latter alloy being shown in Fig. 9 for a 50% reduction. This alloy showed slightly better spring properties than the other with less tin and manganese contents, but the properties of both must be considered good, and their wide range of effective annealing temperatures showed minimum deflections.

An Inductive Dividing Table

By N. M. Barshtak, Z. Ya. Bykova, I. Yu. Klugman, I. I. Knyazhitskyi, and N. P. Rashkovich. (From *Stanki i Instrument*, No. 11, November 1956, pp. 7–8, 7 illustrations.)

The precision of existing dividing tables and heads is determined by the accuracy of manufacture of the components making up the measuring system, but even this degree of precision can be achieved only at the expense of the highest demands on the quality of the components, and any decisive improvement becomes almost, if not entirely, prohibitive in cost. However, with the inductive dividing head described in this article, improved accuracy can easily be obtained.

The operating principle of this inductive equipment, which is intended for the division of a circle into an arbitrary number of equal parts, is based on the integrating method, which makes it possible to obtain a reading accuracy many times greater than that achieved in the manufacture of the components of the measuring mechanism. The essence of the integrating method can be illustrated by the following example :—Assume two circular concentric scales, consisting of n divisions each, having a certain error δ in the divisions of the inner scale and an error Δ in the divisions of the outer scale. Since the scales are disposed around a full circle, it follows that $\Sigma\delta = 0$, and $\Sigma\Delta = 0$. Consequently, when one of the scales, starting from a certain fixed position, is turned through an angle $2\pi/n$, the sum of the distances between the markings of the internal and external scales does not vary. An indicating device responsive to the sum of these distances can therefore perform an accurate division of the circumference of the circle into $2\pi/n$ equal parts, despite the lack of accuracy of the components of the measuring system.

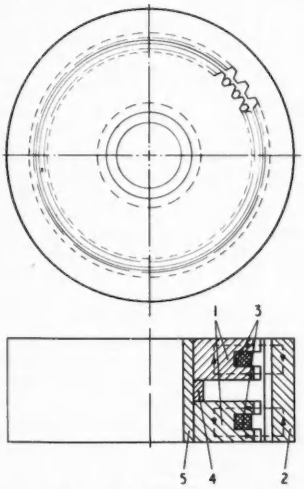


Fig. 1. **Layout of inductive dividing equipment.**

An inductive transmitter is used as the integral indicator in this dividing equipment. The dividing arrangement (Fig. 1) comprises two fixed steel cores (1) and a steel rotating ring (2). The steel cores (1) are made in the form of gear-wheels with external teeth, and each core has an annular groove in which a coil (3) is wound. The rotating ring (2) is constructed in the shape of a gear-wheel with internal teeth, the number of teeth of the core and rotating rings being equal and determined by the number of parts into which it is desired to divide the circumference. Both cores are mounted on a common bronze sleeve (5) and are displaced in relation to one another by half the circular pitch. A bronze spacer (4) separates the two cores, so as to eliminate interference between the magnetic fluxes, and the outer ring rotates freely, when externally driven.

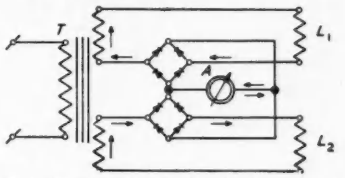


Fig. 2. **Circuit used in inductive dividing equipment.**

The coils of the two cores are connected in a differential phase-sensitive circuit (Fig. 2), each coil being supplied from a separate winding of a transformer T. The voltages of the windings supplying each coil are equal. An electromagnetic micro-ammeter A with a centre-zero scale is the indicating device and is connected through selenium rectifiers. When the inductivities L_1 and L_2 of the two coils are equal, the currents in the arms of the bridge circuit are also equal and flow in opposite directions ; hence, the current in the indicating ammeter vanishes, so that a zero reading reveals equality of inductivities L_1 and L_2.

When the rings rotate around the core, inductivities L_1 and L_2 will vary. Fig. 1 shows (in broken lines) the path of the magnetic flux generated by the coils. The flux traverses the air gaps between the teeth of the core and outer rings, the magnetic resistance of the air gaps depending on the relative position of the teeth. The least magnetic resistance (and consequently the highest inductivity) exists in the air gap when the tips of the teeth are opposite each other, while the lowest inductivity occurs when the teeth are relatively offset by half a pitch.

Owing to the fact that the cores are phase-shifted in relation to each other by half a pitch, the inductivity of one arm will be lowest when that of the other arm is highest. When the outer ring is being turned, the first inductivity will progressively fall, and the second progressively rise, until the first inductivity reaches a minimum and the second a maximum. In some mean position, the inductivities of both arms will be equal and the indicator current will vanish, this position being taken as the zero position. When the outer ring is displaced in one direction from the zero position, the pointer will move to the right, and when the outer ring is displaced in the opposite direction the pointer will move to the left. Thus, the deviation of the pointer serves to detect the magnitude and direction of deviations of the ring from the zero position.

In the vicinity of the zero position, the inductivity is proportional to the sum of all the clearances between neighbouring teeth of the cores and outer ring. Consequently, this inductive pick-up is an integrating measuring device. Thus, when the ring is turned through an angle exactly equal to $2\pi/n$, the indicator readings will be repeated. In particular, when the ring is turned from the zero position through an angle exactly equal to $2\pi/n$, the indicator pointer will return to zero.

Clearly, to divide the circumference, it is sufficient to use a single transmitter (non-differential circuit). The second transmitter then can be replaced by a constant inductivity, equal to the minimum of the variable inductivity. However, the application of two transmitters connected in a differential circuit doubles the sensitivity, and, among other advantages, ensures the repeatability of readings, despite frequency and voltage changes in the electrical supply.

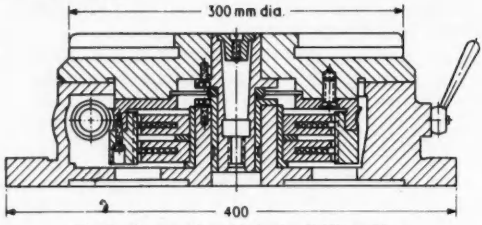


Fig. 3. Cross-section of inductive dividing table.

Fig. 3 shows a cross-section of a dividing table which was tested for dividing a circumference into 360 parts. The rotation of the outer ring, which is rigidly connected to the rotating part of the table, is accomplished by means of a worm and wormwheel, whilst the cores are attached to the stationary part of the table. Unlike dividing tables with mechanical measurement, the worm and wormwheel serve in this instance merely for transmitting motion to the rotating part of the table. The divisions are first read on the coarse scale marked on the stationary part of the table. Fine setting is performed by means of the indicator. The components of the measuring mechanism (core and outer ring) are made on a gear-shaping machine without any further adjustment or machining.

This experimental dividing equipment, which was made from parts of a standard rotary table, was subjected to laboratory tests for accuracy, and the results showed a very high dividing repeatability (about $\pm$ 1 sec), which could be attained after warming up the table for 15 min, and which could be maintained if ambient temperature, frequency, and voltage remained constant. In addition, high sensitivity (4 μA/sec) was obtained.

When the components of the measuring mechanism are made within a limit of 4 min and have an eccentricity of the order of 30 to 40μ, the inductive dividing table ensures an accuracy of the order of 3·5 sec. In this way, as a result of using the integrating method, the dividing error is reduced by a factor of more than 60, compared with the manufacturing error. The accuracy of division of the circumference can be increased several times by further reducing the manufacturing error. A theoretical examination of the relations involved, later confirmed by experiments, has shown that this dividing error is proportional to the square of the manufacturing error. In the design and manufacture of an inductive dividing table, it is necessary to take into account the dependence of dividing error on eccentricity.

The apparatus described makes it possible to divide the circumference into an equal number of parts, but it can also form the basis of a device for continuous measurement of angles.

HOLLAND

The Manufacture and Testing of Extremely Thin Tungsten Wire for Miniature Valves

By L. SCHULTINK and P. G. VAN ZANTEN. (From *Philips Technical Review*, Vol. 18, No. 8, 1956/57, pp. 222–228, 7 illustrations.)

In the manufacture of miniature and sub-miniature radio valves, extremely thin wires of tungsten and other metals are required. In this article, some particulars are given of the manufacture of such wires and of some of the requirements they have to satisfy.

THE general reduction in the dimensions and power consumption of radio valves has led to the employment of extremely thin metal wire in the construction of filaments, grids, and certain other components. Filaments for sub-miniature and miniature valves of the directly heated as well as the indirectly heated type are made of tungsten wire with a thickness of 50 to 6μ. Certain grids, particularly the " frame grids " used in some valves for special applications, are also wound with tungsten wire. Furthermore, tungsten wire is used for some of the smaller components of radio valves, such as hooks and tiny springs for stretching the filaments.

Molybdenum wire, with a thickness varying between 200 and 25μ, is used for the grids of most miniature and sub-miniature valves. This material is further used as a core or mandrel upon which coiled filaments are wound. At the end of the process, the core is removed by dissolving it in a mixture of nitric acid, sulphuric acid, and water. In the case of tungsten wires of much smaller diameter, however, methods of manufacture ensuring the highest degree of accuracy must be employed.

The manufacture of filaments for radio valves was initially based on the experience gained in making incandescent lamps. When, between 1930 and 1940, the coiled-coil filament was introduced and generally adopted, the demands made on the material (tungsten) were necessarily far higher than those made on the earlier used single-coil wires. Manufacturers of radio valves have been able to profit directly from the experience of the lamp industry, though it has, of course, been necessary, in the case of radio valves, to add the well-known oxide-mixture coating (used as an electron-emitting material) to the tungsten filament, the latter acting as the actual heating element. In addition, the special requirements of valves have had to be taken into account. For example, in receiver valves of the directly heated type, tungsten as a cathode material has been superseded by nickel, which provides a better base for the emitting substance. Nevertheless, for certain types of valves, especially sub-miniature valves, there has been a return to the use of tungsten, the main reason being that, for a further reduction in filament current, thinner filaments must be used, and tungsten is more suitable than nickel for this purpose.

The use of thin tungsten wire, however, is not restricted to sub-miniature valves alone. For valves re-

quiring a larger filament current, it is advantageous to use a cathode consisting of more than one thin wire in parallel. The slope of a valve of this construction, for a given anode current, is greater than that of a valve passing the same filament current through a thicker, single wire.

If the cathode diameter is small with respect to the anode diameter, the former has virtually no effect on the slope at a given current. It is further found that, in a cathode consisting of a number of thin wires in parallel, each of these wires contributes about as much to the slope as the amount that can be obtained with one of these wires separately. Hence, by building up the cathode from a number of thin wires, the total slope is increased.

The Manufacture of Very Thin Tungsten Wires

For wire with a diameter greater than 10μ, the normal drawing process, by means of diamond dies, presents no major difficulties. Drawing still thinner wire, however, becomes increasingly difficult. In spite of the considerable tensile strength of tungsten, a pull of only 25 to 30 gm will break a 10μ wire at room temperature ; for a diameter of 7·5μ the breaking stress is reduced to about 15 gm, and for a diameter of 5μ to about 5 gm. Any mechanical working of such wire therefore presents enormous difficulties.

For the drawing of this wire, a whole series of dies is required, each with a diameter differing only very slightly from that of the previous die. It is extremely difficult to drill these very small apertures in the diamonds to the narrow tolerances required. The introduction of spark-machining techniques has admittedly simplified the production of diamond dies with very small apertures but, in spite of the advantages of this process, it is still far from simple to meet the requirements specified above.

The most commonly used method of making very thin wire is by drawing it to the smallest diameter at which it can still be handled, and then further reducing the diameter by an etching process, which can be effected chemically or electrolytically. In the former case, either a gas can be used, e.g., oxygen, water vapour, or chlorine, or a molten oxidizing agent, such as a mixture of potassium nitrite and potassium nitrate. An aqueous solution of an oxidizing agent, such as a mixture of hydrofluoric and nitric acid or of potassium ferricyanide and sodium hydroxide, can also be employed.

A great drawback of all chemical etching methods is the difficulty of carrying out the process with sufficient uniformity. Much simpler in this respect is the process of electrolytic etching, in which the wire is passed through a dilute alkaline solution, whilst a potential is applied between the wire and an electrode placed in the liquid. If the wire is connected to the positive terminal of the voltage source, its diameter will diminish. An attractive feature of this process is that it can be readily carried out continuously and at room temperature. Furthermore, the surface of the wire is thoroughly cleaned at the same time, this being essential for good emission. It is for this reason that wires thicker than 10μ, which could be fabricated by drawing alone, are also subjected to a subsequent etching process.

The use of the etching process imposes severe demands upon the thicker wire to be treated. Its diameter should be as uniform as possible, since any deviations from the nominal value will become relatively greater after etching. In view of the low tensile strength of the wire, the whole etching apparatus must be constructed with the utmost care, and the bobbin from which the wire is reeled off and the guide pulleys should run with a minimum of friction.

To be suitable for filaments of radio valves, the wire must satisfy various specific requirements. Some of these requirements can be conveniently expressed as physical quantities, such as uniformity of diameter, weight and resistance per unit length, tensile strength, and temperature coefficient of resistance.

The diameter of the very thin wires considered here can no longer be accurately gauged with the aid of a microscope. In order to test the uniformity of diameter, moreover, so many measurements must be made that this method is unsuitable for a continuous check during the manufacturing process. Several continuous methods for gauging the diameter during processing have been described in the literature. Thus, in a pneumatic method of gauging, the wire is passed, via two diamond apertures, through a closed chamber into which a gas is fed at a certain constant pressure. If the wire is perfectly uniform in diameter, a constant flow of gas escapes via the apertures in the diamonds. If the diameter is not uniform, on the other hand, the flow of escaping gas will vary, causing fluctuations in the pressure in the compartment. In another gauging method, the wire is passed through a capacitor, variations in diameter thus gauging variations in capacitance. In either case, deviations from the average diameter can be recorded and, by means of special measures, deviations from roundness can also be detected.

The diameter of the wire may also be evaluated from the weight per unit length. In practice, this is always effected by weighing a length of wire of 200 mm with a sensitive torsion balance. In this way, obviously, only the average diameter of the length of wire can be evaluated.

To measure the electrical resistance per unit length during the manufacturing process, the wire is passed through two mercury contacts, the wire between these contacts forming one arm of a Wheatstone bridge. The sensitivity of these measurements can be increased by reducing the distance between the contacts and the speed of the wire.

The tensile strength of the wire can be readily determined by measuring the pull under which a wire breaks. Since this is a destructive test, this value can only be established by sample testing, and not continuously during the manufacturing process. The same applies to the temperature coefficient of resistance. Here, too, samples are taken and tested by measuring the resistance at various temperatures in a Wheatstone bridge.

Among the requirements which are difficult to define or measure as physical quantities are creep, brittleness, roundness, " straightness ", surface texture, and the presence of splits. While creep may be negligible at room temperatures, it can be considerable at the high temperatures at which a valve filament operates. As a result, the stress in the filament will be reduced, thus increasing the risk of microphony. If the tensile load is large, the wire may even break. To obtain data of practical significance, creep should be measured at high temperatures. This measurement requires high-precision equipment and is, moreover, very time-consuming. For these reasons creep measurements as such are as a rule dispensed with, although information of practical value in this connection is often obtained as follows :—Samples of the wire are taken and, by means of a small weight or a spring, each wire is subjected to the same tensile stress, which is a multiple of the normal filament stress. The wires are heated to about 800°C by means of an electric current. If the time elapsing until the various wires break is noted, a curve may be plotted of the number of unbroken wires as a function of time. The form of this " survival curve " varies according to the process and conditions of manu-

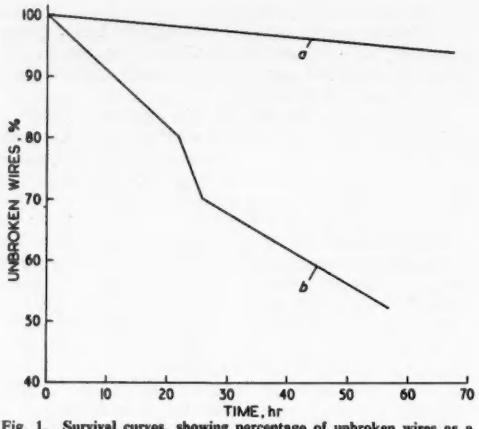


Fig. 1. Survival curves, showing percentage of unbroken wires as a function of time, for (*a*) a good-quality wire, and (*b*) a poor-quality wire.

facture of the wire. Two such curves are shown in Fig. 1, for a good-quality wire (curve *a*) and a poor-quality wire (curve *b*), the wires in this instance having been heated in a vacuum up to 775°C and, as mentioned, subjected to a tensile stress which is a multiple of the normal filament stress. With the aid of survival curves of a given batch of wire, it is possible for designers to decide what voltage and tension can be applied to the wire, without increasing the risk of broken filaments above an acceptable limit during the normal life of the valve.

Brittleness is generally assessed by bending the wire through a given angle over an edge of a certain radius and counting the number of times this can be repeated before the wire breaks.

For judging roundness, it is possible, but rather difficult, to detect slight discrepancies in the circular shape of the cross-section of the final product. A preventive check on the aperture of the last die through which the wire is drawn is generally more effective.

As a check on the presence of irregularly distributed internal stresses, a given length of wire is often freely suspended and the extent to which the wire deviates from a straight line is observed. For the sake of brevity, this is often referred to as the " straightness " of the wire.

The surface texture of the wire can be altered considerably by etching. The surface may vary from glossy to dull. As an example, Fig. 2 shows the surfaces of two wires etched by different processes.

The detection of local cracks in the wire is extremely difficult. Even with the aid of a microscope, it is very hard to determine whether a wire is cracked or merely shows a deep groove. The issue may be decided by examining a lateral cross-section. Usually, cracks occur when the wire in other respects is also in a generally poor condition.

Coating of Wires

For use as cathodes in radio valves, the wire must be coated with the carbonates of barium, strontium, and sometimes calcium. There are two methods of coating, i.e., continuous immersion and electrophoresis. With continuous immersion (" drag coating ") the wire is passed several times through a suspension of the alkaline earth carbonates, to which is added a certain amount of the nitrate of one or more of the above-mentioned metals. Each time the wire is passed through the suspension, a thin layer adheres to the wire, which is subsequently sintered to the surface by heating. The nitrates serve as an inorganic binder. The layer thickness obtained depends on the speed of the wire, the viscosity of the suspension, and the number of times the process is repeated.

In the electrophoresis method, the wire is passed through a bath containing a suspension of charged carbonate particles. Under the influence of a voltage applied between the wire and an anode in the suspension, the carbonate particles migrate towards the wire, to which they adhere. Appropriate selection of the voltage and speed of the wire makes it possible to obtain the desired layer thickness in one operation. After drying, an additional coating is deposited by passing the wire through a solution of a binder.

When the radio valve is being exhausted, the wire must be heated, in order to convert the carbonate into oxides. At the same time, any organic binder present is carbonized and burnt.

When tungsten is heated with barium carbonate or barium oxide, certain reactions occur with the metallic tungsten. Thus, at a temperature of approximately 600°C, a reaction involving the formation of barium tungstate and carbon monoxide is initiated. Since the formation of the semi-conductive barium tungstate is undesirable, this reaction should be avoided.

If the temperature is quickly raised to between 800 and 900°C, the barium carbonate decomposes to barium oxide and carbon dioxide. If, however, the temperature is raised above 1000°C, the barium oxide is reduced by the tungsten, forming barium tungstate and free barium. In this way, the free barium required for the proper functioning of an oxide cathode is obtained. In view of the fact that only a small quantity of free barium is required, whilst at the same time the formation of the semi-conductive barium tungstate is undesirable, heating at high temperature should take place for a short period only.

The last reaction probably also occurs, if only on a very small scale, during the normal functioning of a radio valve ; the free barium lost through evaporation or combination with residual gas is thus compensated.

On normal indirectly heated oxide-coated cathodes, a carbonate layer with a thickness of 75μ is usually deposited. For a directly heated cathode with a diameter of only 8 or 11μ, such a layer is obviously far too thick. The usual layer thickness on a tungsten wire of 11μ is 20μ, and even here the ratio of the diameter of the coated wire to that of the tungsten core is so great that the temperature of the core differs a great deal from that at the surface. It is owing to this temperature difference, however, that thin cathodes with a tungsten base can retain a better activity than thicker cathodes. As tungsten is a rather poor reducing agent for the alkaline-earth oxides (as compared with silicon, magnesium, or aluminium, which are alloyed in normal cathode nickel), a high temperature of the core is required to ensure a permanent supply of free barium. The temperature at the surface, however, determines the rate at which the barium disappears through evaporation and combination with residual gas, and here a not-too-high temperature is favourable.

It is interesting to note that, for a given filament current, the temperature of the core depends very little on the thickness of the coating, unlike the temperature at the surface, which is strongly correlated with the thickness.

Results of Life Tests

The emission current that can be supplied by an oxide-coated cathode with a core of thin tungsten wire is difficult

(a)

(b)

Fig. 2. Influence of etching process on surface texture, showing (a) a roughly etched, and (b) a smoothly etched wire. (× 16,000)

to predict with any accuracy, since this depends greatly on the purity of the materials involved. The quantity of oxide on a length of wire of 2 cm having a diameter of 11μ amounts to approximately 30μg. If it is assumed that 0·01% of this consists of free barium, it follows that 0·003μg of active material is available on the cathode. Clearly, the production of valves in which the quantity of free barium remains roughly constant during the entire working life, whilst at the same time the formation of undesirable tungstates is kept within reasonable limits, calls for the strictest precautions and the highest precision. A further requirement is that the filament voltage should be permitted to vary within the wide limits between which the terminal voltages of dry batteries are apt to vary. Nevertheless, it is found possible to obtain satisfactory results in practice.

U. S. A.

Fluidized Plastic Coatings for Corrosion Resistance

By J. A. NEUMANN and F. J. BOCKHOFF. (From *Product Engineering*, Vol. 28, No. 1, January 1957, pp. 140–143, 7 illustrations.)

IN the process known as fluidization coating, the parts to be coated are heated above the melting range of the plastic and then immersed for a few seconds in a bed of specially prepared plastic powder, maintained in a bubbling or "fluidized" condition by compressed air or inert gas. On removal, residual heat melts and levels the adhering powder particles to a smooth, non-porous resin coat, forming an adherent, tough, and corrosion- and electrically-resistant cladding. Plastics used at present include polyethylene, nylon, some polyethers, and certain fluorothenes. Conceivably, however, any thermoplastic resin may be used for fluidization coating, provided that it exhibits reasonable stability against degradation and oxidation above its melting range.

Advantages of the process include the fact that (1) components, ready for use, can be produced in a short time; (2) solvents are eliminated, thereby improving coating porosity, compared with dispersion or solution types of coatings; (3) thick coatings can be applied in a single dip, without sagging, running, or crazing, while, on heavy metal parts, coatings up to 100 mils can be applied in a few dips without cure or cool-down between immersions; (4) coatings are uniform in thickness, since the scrubbing, turbulent action of the fluidizer reaches the most recessed areas of the part; (5) there is no material loss, compared with spraying, when coating open-meshed or small objects; and (6) portable fluidizers can be used where on-the-spot protection must be applied.

The absence of solvent or plasticizers develops maximum corrosion resistance in polyethylenes or fluorothenes. Plasticizer blends are not required, as in plastisol application, removing the problem of age embrittlement caused by leaching or migration of plasticizers.

MECHANISM OF FLUIDIZATION

Fluidized plastic powders have been used for coating applications since 1948, though the technique was not publicized until the issue of a British patent in 1950. Fluidization may be defined as an operation in which a mass of solid particles, usually finely divided, is maintained by means of an upwardly moving gas stream in a turbulent, dense state. The gas used is either compressed air or nitrogen, depending on the oxidation tendency of the polymer.

The principal pressure gradient required for fluidization is that required by the gas to overcome friction in the bed of closely packed powder. When the pressure drop across the bed approaches the weight per unit area of the bed, the solids begin to move. This represents the initiation of fluidization, similar to the bubbling of a gas through a liquid. Splashing occurs and streamers are occasionally

ejected above the surface of the fluidized bed. When the container is tipped or rocked, the fluidized-powder bed behaves like a liquid.

As gas velocity and pressure drop increase through the bed, the mean free path of the powder particles increases, gradually increasing bed porosity. Variation of pressure drop through the bed with superficial gas velocity is shown in the generalized curve in Fig. 1. Portion *AB* of the curve represents fixed-bed operation ; no motion of particles is observed, and the porosity of the bed remains constant. At point *B*, the resin particles begin to move and the bed becomes unstable. Point *C* represents the loosest arrangement of the particles which can remain in contact, indicating the beginning of fluidization. From *C* to *D* the bed expands in volume, with a consequent increase in porosity. At *D* fluidization is complete. Further increases in gas velocity beyond *D* give only slight increases in pressure drop, owing to increased fluid friction and entrance effects.

The optimum condition of operation is point *D*, which represents the minimum required pressure drop and superficial gas velocity for complete fluidization. A higher gas velocity creates an undesirable increase in bed porosity, requires greater gas consumption, and causes cooling of the part being coated. At point *D*, porosity is high enough for easy dipping of the articles to be coated.

Coating Process

The part to be coated is heated to a temperature above the melting point of the resin powder and submerged in the fluidized bed. Powder particles, in contacting the hot surface, form a partially melted coating whose thickness is dependent on several factors, i.e., (1) ratio of weight to surface area, (2) preheat temperature, (3) fusion temperature of polymer, (4) thermal conductivity of polymer, (5) immersion time, (6) specific heats of polymer and object, and (7) density of polymer. For example, the relationship between coating thickness, preheat temperature, and immersion time for the coating of a steel panel, $4 \times 8 \times \frac{1}{16}$ in., with low-modulus polyethylene is shown in Fig. 2. Curves vary considerably, depending on the polymer and the geometry of the part being coated. For an object having a greater weight-to-surface area ratio, the coating thickness would be proportionately greater.

After withdrawal from the bed, the outer surface of the coating is still grainy and unmelted. However, additional heat is soon conducted from the part to the coating surface, causing complete fusion and levelling the coating. Occasionally, thin-walled objects do not furnish the required heat necessary for complete fusion after immersion. In these cases, a post-heating period in an oven is required.

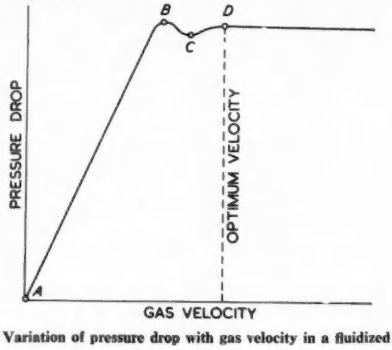


Fig. 1. Variation of pressure drop with gas velocity in a fluidized bed.

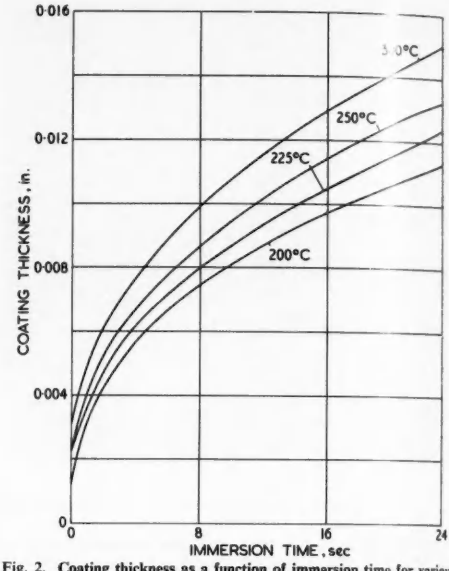


Fig. 2. Coating thickness as a function of immersion time for various preheat temperatures.

The kinetic energy of the fluidized particles is sufficient to provide good adhesion to most properly cleaned metal surfaces. Coating adhesion, however, can be further improved by using proper pretreatment. Treatment is generally of the surface-conversion type and is specific for various types of metals.

Commercially available fluidization powders are modified to provide greater adhesion, better free-flow properties, and better general operating characteristics. In most cases, non-modified powder plastics will not provide satisfactory operation.

Applications

Several prepared powder blends are available for various temperature conditions and corrosion-resistant requirements, among these being conventional polyethylene, linear polyethylene, and nylon, with maximum service temperatures of 170, 240, and 300°F respectively. Fluidized coatings of these materials are applied to such laboratory items as clamps, spatulas, test-tube baskets, support racks, electrical components, trays, fasteners, small containers, and electrically insulated tool handles. Commercially, fluidized coatings are used for strainers, filter plates, wire screens, impellers and other stirring equipment, pickling and dipping baskets, gaskets, flanges, valves, pump parts, bellows, rollers, and various types of floats. The process can also be applied to specially shaped items by conducting fluidization entirely within the item to be coated, e.g., in tanks. With regard to the cost of fluidization coating, it is hard to generalize, but, as a rough guide, it may be said that the total cost, using a polyethylene powder modified for fluidization, varies between $1.00 and $5.00 per square foot, depending on complexity of shape and the preparatory work necessary.

In many applications fluidized plastic coatings provide quick, convenient, and economical protection against corrosive environments. Adaptation of the fluidized coating process to continuous coating methods is under development ; continuous wire and screen coatings appear entirely feasible.

British Industrial Developments

Injection-Moulding Machines

It is announced by Wickman Limited, of Coventry, that a new department has been formed at the works of Cravens Limited, of Sheffield, to manufacture in Great Britain the completely redesigned range of injection-moulding machines produced by The Hydraulic Press Company, of Mount Giliad, Ohio. The present range now in course of manufacture includes the 12-, 20-, and 48-oz machines, with locking pressures of 300, 400, and 800 U.S. tons respectively. Larger machines, up to a capacity of 400 oz can, however, also be constructed.

Of neat and clean design, these machines embody a number of novel features, yet retain their characteristic long stroke and daylight. A new hydraulic circuit has been designed, incorporating manifold-mounted valves accessibly located at the rear of the clamp closing and injection cylinders, eliminating extensive pipe-work, leaks, and overheating. The main oil-supply tank, of ample capacity, is located above the clamp closing cylinder, preventing cavitation and eliminating possible contamination of oil through plastic material, water, or other foreign matter. At the same time, however, the tank is readily accessible for filling or draining.

By virtue of the design incorporating straight-line hydraulic locking, mould set-up time is reduced to a minimum. Adjustment for fast approach and slow down speeds, etc. is carried out easily and quickly by means of limit-switches conveniently mounted on slide rails positioned at the front of the closing cylinder, these switches being enclosed, to prevent damage or unauthorized adjustment. Platens are of ample proportions and are drilled and tapped in accordance with the recommendations of the British Plastics Federation.

The injection unit is fitted with a special high-output plasticizing chamber of proved design, providing a very high rate of plasticizing and fitted with three heating zones, each pyrometer being provided with a suitable controller. The chamber mounting is by means of a simple, yet effective, wedge-lock, eliminating the use of screws. Material feed is effected by a very accurate weigh-feed unit designed and constructed by Southall and Smith, of Birmingham. Provision is made for run-through, if desired, and for feeding sprues and runners.

With the new hydraulic circuit used, high injection speeds are possible, and pressure control is instantaneously adjustable by means of control valves located under large dial-type pressure gauges. The injection plunger is advanced to shooting position during the hold-on phase of the cycle, and an additional timer is fitted, allowing double feeding of the chamber for large-capacity shots. The entire injection unit is mounted on ways operated hydraulically, thus giving hydraulic loading of the nozzle and providing a sprue break action at the option of the operator. The entire unit can be easily retracted to gain access to the rear of the fixed platen or for purging of the chamber. Both clamp and injection units are securely mounted on a fabricated base designed to provide maximum clearance under the die-mounting area, and with the minimum of restriction. The machines are provided with a safety gate, electrically and hydraulically interlocked, and a rear guard, also electrically interlocked with the operating sequence.

Streamlined Welding Helmet

Of one-piece construction and streamlined to improve both comfort and appearance, a new welding helmet announced by Fleming Safety Goggles, of London, E.C.1, has deeply curved sides, giving good protection against side-flash and reflected radiations. The total weight of the helmet, with filter and cover-glass, is only 23 oz.

The glass-holder is of shock-resistant plastic and takes filters of $4\frac{1}{4} \times 2$ in. The coloured filter is of Protex glass and is protected by a clear cover-glass. Changing filters or replacing cover-glasses, as required, is very simple. The headband is lined with a replaceable sponge sweat-band, which is washable. The sponge is soft when damp, is non-irritant, and is always comfortable in wear. The size of the headband is controlled by a hexagonal nut, and precise adjustment, to give perfect fitting, is achieved by fingertip control. The helmet is also fitted with a chin-strap, which can be adjusted for size, and the helmet remains firmly in position when swivelled above the head. A welding handshield of similar shape and construction, is also available.

Bursting Discs for Pressure Vessels

The production in quantity of bursting discs of ductile metal foil, with accurately controlled bursting pressures, together with suitable holders to suit requirements, is announced by The Distillers Company Ltd., of Great Burgh, Epsom, Surrey. These discs are available in a wide range of materials, including nickel, Monel, stainless steel, silver, aluminium, and platinum, but discs of other materials can also be supplied, if required.

Provided that adequate care is taken in manufacture and fitting, a bursting disc provides one of the most reliable devices for the protection of pressure systems. Before rupture it provides a complete and effective seal, whilst its bursting pressure can be forecast with considerable precision. On rupture it provides an unrestricted passage for the relief of excess pressure. Furthermore, it has very little inertia, and consequently there is a minimum of delay in the response of the disc to pressure rises. A very attractive feature is its intrinsic safety. No matter how a bursting disc is treated, it will not burst at a pressure higher than that for which it was designed. Damage of any kind, faulty fitting, corrosion, and high temperatures all tend to reduce the rupture pressure. Deposition on the disc of polymerized resins, sublimates, gums, etc. does not generally affect the bursting pressure.

In the design of these new discs, use is made of ductile metal foils with clearly defined metallurgical and mechanical properties. When clamped beneath an orifice ring having a smooth radius on the inner edge, the disc will extend, when subjected to pressure, taking up the form of a segment of a sphere. The metal at the centre of

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the disc thus becomes thinner as pressure increases, until it eventually ruptures. In this connection, these discs have been produced with bursting pressures as high as 25,000 psi; in addition, discs which are suitable for operating at very high temperatures have been made, and in one instance discs have been used at 430°C.

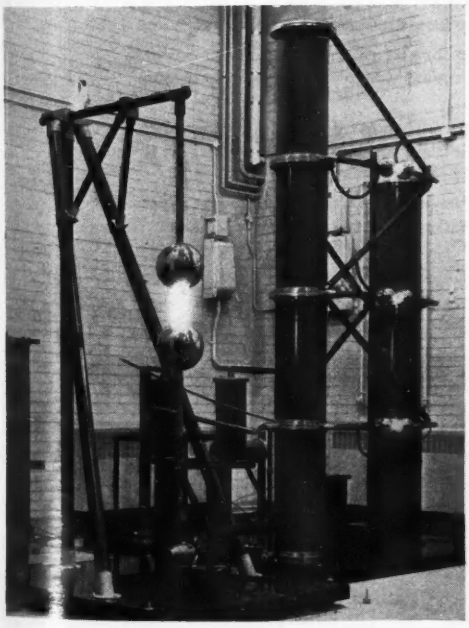
With regard to the holders for these discs, stainless steel is normally recommended, but other materials can be used, according to the particular application.

Extension to Crompton Parkinson Research Laboratories

To maintain progress in the technical development of their products, Crompton Parkinson Ltd., of London, W.C.2, have recently opened a new extension to their Development and Research Laboratory at Chelmsford. Of a modern architectural treatment, the new building provides an additional floor space of 8000 sq ft. Apart from the new research facilities now available, transfer of technical staff to the new premises has also allowed further expansion and improvements to take place in the existing chemical laboratory, workshop, and materials-testing sections.

The new laboratory includes a high-voltage section housing a 350 kV impulse generator (illustrated), designed and built by the company. This equipment is intended primarily for development work on switchgear and associated equipment, but it will also be available for tests on other products, should the occasion arise. At the moment, the generator has three stages, but it can be extended to higher voltages, if considered necessary. Power-frequency testing up to 100 kV is available. Associated equipment in this new laboratory includes a Schering bridge, ionization detector, transient recorder, and control gear, much of this equipment having been designed and built by the Department. The new high-voltage laboratory is additional to the existing 2·1-MV impulse laboratory in the Company's B.E.T. transformer works, at Hayes, Middlesex.

For dynamic tests on machines and other equipment, a test-bed, with complete electrical services, a.c. and d.c., has been installed on the ground floor. In the same area, a Ward-Leonard set with electronic control has been constructed, and this is intended to be a flexible unit for drives up to 40 hp; alternatively, it can be used for supplying a.c. with a high degree of stabilization of voltage and frequency for special laboratory services. Dynamometer facilities up to 20 hp are also provided.



In addition, a new and well-equipped microscope room has been built, with its own associated dark-room for photographic reproduction. Apparatus includes a 35-mm camera for use with a microscope and with a built-in electronic exposure meter. Grinding and polishing are carried out in a separate room, to prevent abrasive dust damaging the optical equipment. The photographic section has been enlarged and is responsible for a Barcro reproduction process and numerous other photographic applications.

The top floor of the new building accommodates a library and light electrical engineering department which includes electronic and instrument sections. The electronics section is concerned mainly with the development of test and control equipment of a special nature.

The instrument section is concerned with the design and construction of special electrical instruments, non-electronic, which may be required for works process control or component testing. In addition, this section is responsible for a temperature-controlled standards room, which is used for checking and calibrating all instruments used by the Department.

Multi-Cell Cyclone Dust Collector

The multi-cell cyclone mechanical dust collector presents an economical and efficient solution to many of the problems involved in the elimination of atmospheric pollution arising from the stack emissions of all types of boilers. The Holmes-Rothemuhle collector is the latest of this type to become available in the U.K., where it is being manufactured and marketed under licence by the Gas Cleaning Division of W. C. Holmes & Co. Ltd., of Turnbridge, Huddersfield. High dust separation efficiency is derived from the relatively small diameter of the individual cyclones comprising the complete unit. By using a number of such cyclones in parallel the pressure drop across the unit is kept to a minimum.

A unit cell consists of two concentric tubes, i.e., an outer flue-gas cylinder with an impeller fixed at the inlet, and an inner clean-gas pipe. An intense swirl is imparted to the dust-laden gas as it enters the cell, causing the dust particles to be centrifuged to the annular collecting space. The dust then gravitates to hoppers below, whilst the cleaned gas is drawn through the inner tube into the outlet ducting. The complete collector comprises a honeycomb of unit cells welded together to form a compact, rigid structure. The impellers are about 4 in. in diameter and are cast from abrasion-resistant alloy, whilst the tubes and plates are of mild steel. As no secondary cyclone collecting is necessary, operating costs are kept to a minimum.

A striking feature of the cell assembly is its economy in space occupied, enabling it to be conveniently located in the flue-gas ducting. The collector itself is always inclined, since the back-plate forms a chute for conveying the separated dust into the hoppers, but the gas in-flow may be either axial with the inclined cells, which is the normal arrangement ; vertically downwards, e.g., the collector may be located beneath the economizer ; or horizontal, which is useful when the collector is combined with an electrical precipitator. If conditions demand a vertically upward gas inlet, an alternative arrangement, using a reverse-flow cell, is used.

Dust collection efficiency depends on several factors, including particle size and density. This collector has a high separating efficiency, which is maintained over a wide range of dust burdens and gas volumes. Low linear duct velocities are used, so that pressure loss is low and little additional power is required for operation. Maintenance costs are negligible, since there is no wear and tear.

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The Holmes-Rothemuhle collector is stated to be immune to blockage but, even in the unlikely event of a complete choking of the dust-collecting annulus, boiler operation will not be interrupted ; only the dust separating process will be temporarily halted, and this will automatically restart on removal of the bunker ash. This collector is suitable for a variety of problems, ranging from the removal of fly-ash from boiler flue gases and collection of unburnt combustible matter for re-circulation into boiler furnaces, to separation of dust in extraction systems in foundries and recovery of valuable fines from crushing, grinding, and drying operations.

Centrifuge for 100*g* Loads

A centrifuge which can impose alternate positive and negative acceleration loads as high as 100*g* has been designed and built by the Flight Development Establishment of D. Napier & Son Limited, of Luton, Bedfordshire, for testing components and auxiliary services of rockets, guided missiles, and high-speed aircraft under simulated flight conditions. This centrifuge is one of the most powerful and versatile of its kind in Great Britain, and is capable of providing precise information on the effects of violent accelerations, such as those reached in missile launching and high rates of manoeuvre during interception, and on servo-mechanisms, control units, propulsion systems, and similar items.

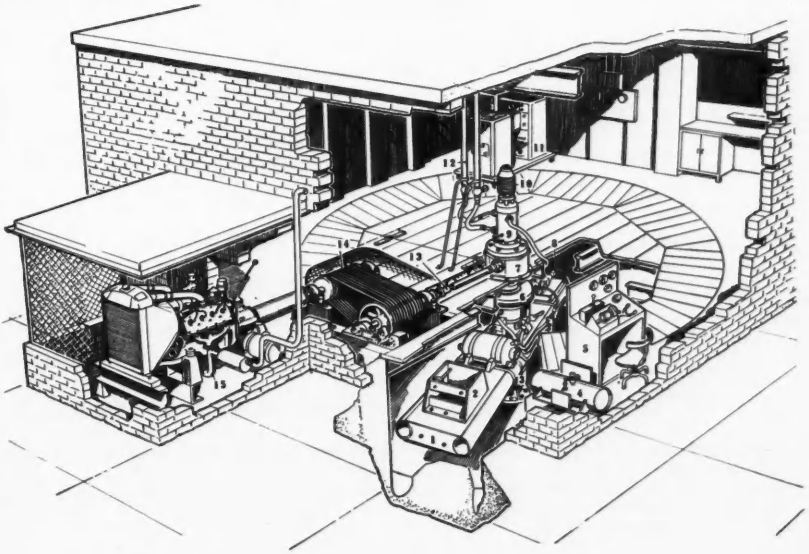
The 19-ft arm of the centrifuge is a welded beam made from two 8-in. steel tubes, faced with boiler-plate on both top and bottom surfaces and mounted on a vertical hollow shaft driven by an industrial petrol engine. This shaft consists of two coupled parts, the lower of which forms the pivot of the centrifuge and runs in roller bearings, the weight of the structure being supported by a thrust bearing on the floor of the well. The upper section runs in ball bearings and transmits the drive to the pivot via a resilient coupling. As a safety precaution, the centrifuge is housed in a concrete-lined well, 25 ft deep. One end of the arm carries an auxiliary turntable mounted on a spindle and connected by spur and bevel gears to the centrifuge transmission system. A clutch enables the turntable to be rotated under power for the application of alternate positive and negative *g*, or to be locked in any desired position. The turntable can have top plates of 10 or 20 in. diameter, but heavy test equipment can be mounted directly on the centrifuge arm, if necessary. Lead weights are fitted into a welded steel box at the other end of the arm to counterbalance the weight of the equipment under test.

On the roof structure of the centrifuge well is the main-shaft bevel drive which is connected via an enclosed shaft to the power plant, which develops 85 bhp and is fitted with a clutch and three-speed gearbox. Low gear gives a centrifuge speed of 0 to 90 rpm (0 to 25*g*), second gear 90 to 200 rpm (25 to 100*g*), and high gear 210 rpm for continuous running at 100*g*. Above the bevel drive gearbox, an extension to the vertical main shaft accommodates a three-way distributor, through which air or fluids may be fed to the equipment under test. Duplicated connecting pipes from the distributor run down the main shaft and along the centrifuge arm to pick-up points adjacent to the auxiliary turntable. Two of the channels may be used to maintain a return flow system, leaving the third channel for use as a pressure or vacuum line, or for the supply of a non-volatile and expendable fluid, which can be jettisoned into the centrifuge well.

A group of 19 shielded slip-rings for low-voltage electrical supplies and instrumentation purposes is mounted above the fluid distributor. These rings are of polished stainless steel fitted with silver-morganite brushes, leads from the slip-rings passing down the hollow main shaft to a group of oscillators. A further group of 6 slip rings, situated at the base of the main shaft, supplies electrical power up to 20 A at 450 V.

A number of auxiliary services is built into the installation. Thus, air pressure is available from a main supply line; high-altitude conditions are simulated by two vacuum pumps; and nitrogen gas is supplied direct from high-pressure bottles at up to 1000 psi. Electrical supplies include 24 V d.c., 240 V single-phase, and 415 V three-phase. For oscilloscope recording, a 10-channel unit designed and manufactured by Napier is provided.

Water is used as a substitute for the actual propellants when the functioning of rocket engine components, propellant tanks, and control systems is tested, the water being expelled from a 130-gal tank by high-pressure nitrogen. By this method, very high flow rates are achieved at pressures up to 1000 psi. Ram-jet fuel-system units are supplied with kerosene fuel from a large-capacity circulating system capable of maintaining flow rates of 3500 gal per hour at a pressure of 400 psi for indefinite periods.



(1) Centrifuge arm.
(2) Counterweight box.
(3) Slip-rings for electrical power.
(4) High-pressure water-expulsion rig.
(5) Centrifuge control unit.
(6) Vertical main shaft.
(7) Main-shaft bevel drive.
(8) Equipment under test.
(9) Three-way fluid distributor.
(10) Slip-rings for low voltage and instrumentation.
(11) 10-channel oscilloscope.
(12) Kerosene supply from adjacent pump-house.
(13) Transmission shaft.
(14) Multi-belt drive.
(15) Industrial power unit.

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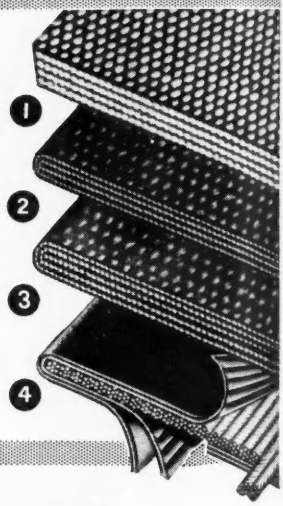

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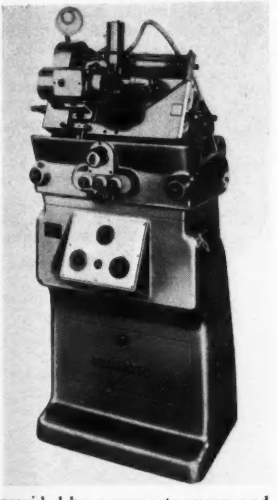
Automatic Magazine-Fed Gear-Cutting Machine

Designed for the high-precision production of instrument gears, toothed sectors, pinions, splined shafts, and components with radially drilled holes, the "Frimatic" gear-cutting machine, manufactured by J. P. Friat et Cie, of Bienne, Switzerland, is now available in Great Britain from the sole U.K. agents, Broadway Equipment Limited, of London, N.W.3. The machine, which is fully automatic and magazine-fed, has a nominal capacity of 1¼ in. blank diameter by 1 in. length (or 2 in. on request), with a maximum tooth size of 24 D.P. in brass or 48 D.P. in steel, and a maximum number of teeth of 120. It can cut pinions to 0·02 in. diameter and teeth to 300 D.P.

In operation, a component is delivered automatically from the magazine, after which the roughing cutter is lowered into position and the table feed applied. At the end of the cut, the cutter is raised and, whilst the component is indexed to the next position, the table returns rapidly, the cycle repeating until the component has been completely indexed. At this point, the cutter spindle reverses rotation and moves axially, bringing into position the finishing cutter, and the component is once again indexed through the full 360 deg. The finished component is then ejected, and a new blank takes its place.

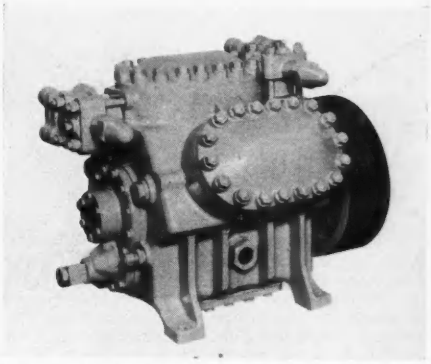


The cutter arbor is driven via a steplessly variable-speed d.c. motor at between 800 and 4000 rpm, the speeds for both roughing and finishing being preset and controlled electronically. The machine is designed for use on a.c. mains. The magazine and loader has its own separate electric motor, but all other movements are actuated by a low-pressure hydraulic system powered by a separate pump and electric motor. Feed and return table movements are variable in speed and adjustable individually. Cutting oil is provided by a separate sump and gear pump. All movements, either radial or axial, and in particular the table traverses, are on caged steel balls.

In addition to this fully equipped model, others are also available, both bench and pedestal, with fixed or infinitely variable cutter speeds, for single or for roughing and finishing cutter operation, and with or without automatic loaders, and helical and bevel gear milling and radial drilling attachments.

High-Speed Single-Acting Freon Compressors

A new range of high-speed single-acting freon compressors, giving an extremely high-capacity refrigerating output for the floor-space occupied has been designed by the Lightfoot Refrigeration Co. Ltd., of Wembley, Middlesex. The first of this new range, which will be available in 4- or 6-cylinder units, is the W.225, 6-cylinder compressor (illustrated). This machine, which has a maximum speed of 1450 rpm, can be fitted with unloading gear for "no-load" starting, and will be available with three-stage capacity control, if required.



The crankcase, of *en bloc* design, is fitted with removable liners and forms a substantial reservoir for oil. A gear pump driven by the crankshaft supplies forced lubrication to all bearings and provides the necessary oil pressure for the unloading equipment or capacity control, if fitted. The compressor valves, which are manufactured from special alloy, are of the low-lift ring-plate type for durability and quiet operation, and the main service stop valves, which are mounted on top of the crankcase, are provided with sealing caps against refrigerant leakage.

Electronic Reading Machine

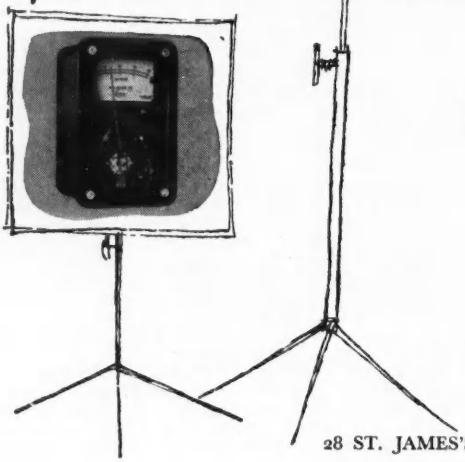
Although the latest electronic office machines, industrial computers, etc., can now perform their required functions at very high speeds, bottlenecks occur, primarily because their input, whether effected by signals from an electric typewriter, punched cards, or punched tape, is limited by the speed of the human operators who transfer or interpret the basic written information into these media. However, the Solartron Electronic Reading Automaton (ERA), developed by Solartron Business Machines Ltd., of Dorking, and The Solartron Electronic Group, Ltd., of Thames Ditton, Surrey, have eliminated this bottleneck by providing, as it were, the missing link in the chain of initial information to final collation, by directly reading input information at speeds and with an accuracy far greater than those obtainable by human agency.

The Solartron ERA can, in its present production pilot model, read at the rate of 120 characters per second. The actual production version, of compact and streamlined design, will, however, be capable of far greater speeds, i.e., 300 to 600 characters per second. The machine incorporates a special all-electronic flying-spot scanning device, which reads figures, etc., on papers, stock-cards, tickets, cash-register rolls, and any other form of document or printed matter, irrespective of whether these items are stationary or moving. Furthermore, if required, the scanner can skip unnecessary parts of documents and can read only what is required, e.g., the figures on banknotes, postal orders, and cheques, without having to move the document about specially. When the information has been read, it is electrically conveyed to the actuating mechanism, e.g., a card punch, which can then be operated at speeds many times greater than those possible by human operation. Thus, for instance, the ERA can punch cards, when arranged to do so, no less than 144 times faster than human punchers working at a rate of 300 cards per hour.

The unique feature of the new reader is its ability to identify positively and accurately a number of characters, the simplest application being the recognition of the figures 0 to 9, with a number of letters and plus and minus signs. It should be understood that, although attempts have been made in the past to develop reading machines, they have not been successful, mainly because

What's the score?

An unusual looking baton? Certainly; and a most sensitive one. It is, in fact, the needle of an Austinlite marginal relay, a piece of equipment much in demand wherever very small variations of voltage or current are used for control purposes. We designed it in the first place for control equipment of our own, because nothing quite sensitive, and at the same time robust, enough was available. Now it is standard equipment. That is how most Austinlite equipment originates: we design something for an unusual job and build it. Other people hear about it . . . we get enquiries . . . and so it becomes standard. Have you, perhaps, a non-standard enquiry to make?



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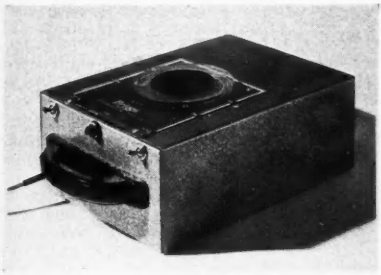
of imperfections in what may apparently be perfect calligraphy or printed material. Thus, the figures in the average business document which would have to be handled by machines of this kind are usually distorted, smudged, defective, broken, and/or misplaced, while additional complications may be introduced by the style of type-face or even dirt, folds, and other blemishes on the paper itself. As a result, it will be appreciated that, unless special precautions are taken, misinterpretation in reading can only too easily occur. The Solartron ERA overcomes these difficulties by providing such a multiplicity of identifying operations that, by virtue of what may be termed their redundancy, imperfections, mutilation, etc., are taken into account, and accurate interpretation is ensured, without the need for special type-faces.

It must be emphasized that ERA does not itself store or in any way treat the information it has gathered. Its purpose is simply to identify and to convey the information it reads to the many types of machine already available for dealing with the information, as required, at very high speeds. In other words, it now makes modern computing and office machinery fully efficient by feeding in information as quickly as the machine can take it.

High-Speed Electronic Stroboscope

Preliminary details of a new high-speed electronic stroboscope are announced by the Dukes and Briggs Engineering Company Ltd., of Altrincham, Cheshire. The new instrument, which is an addition to their existing range of stroboscopic devices, covers the range between 7000 and 40,000 flashes per minute on fundamental but, by using up to the fourth harmonic, enables observation to be made up to 160,000 rpm. The design is such that it is suitable for holding in the hand, permitting it to be conveniently used for the measurement of shaft and spindle speeds and for the observation of cyclic operation of moving parts of machinery. Thus, one particular application is in the textile industry for observation of the behaviour of high-speed bobbins.

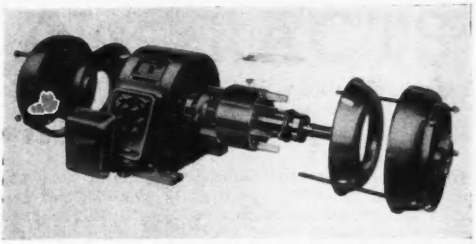


The new stroboscope, which is mains-operated, comprises a thermionic valve oscillator feeding the light source, the frequency of oscillation being controlled by adjustment of a pointer on top of the instrument. A calibrated scale covers the frequency range between 7000 and 40,000 flashes per minute. Built-in calibration is provided, and a switch facilitates change of range coverage of scale-setting times of 0·5 or 1·0.

Drip-Proof Electric Motors

With the addition of their new range of drip-proof motors in the smaller horsepower group, i.e., from ½ to 50 hp, Newman Industries Limited, of Yate, Bristol, are now manufacturing a complete range of drip-proof motors from ½ to 600 hp, suitable for all applications where the protection afforded by drip-proof enclosure is considered of value.

Although the new motors are basically of the normal squirrel-cage induction-motor type, they embody a number of innovations in design and construction. Thus, they have been built to draft British Standard Specification CW(ELE)6246 and BS.2613 amended to include Class "E" insulation. In addition, they incorporate improved ventilation, provide more complete protection, and have excellent electrical performance, as a result of a new insulation technique. Other features include versatility of mounting and application, a dynamically balanced die-cast rotor which ensures vibration-free running, and a new design of terminal box which speeds up wiring and installation.



Multi-Pole Miniature Circuit-Breakers

The introduction of double-pole and triple-pole versions of their "Lupus" miniature circuit-breakers, thereby completing their range up to 60 A, is announced by the M.C.B. Co. (Manchester) Ltd., of Altrincham, Cheshire. Both these new types are designed on the unit-assembly principle, being built up from complete single-pole miniature circuit-breakers.

The operating mechanisms are linked externally and the trip mechanisms internally, the hole for the link-pin being the only communication between adjacent poles, which are otherwise completely insulated from each other, thereby precluding any risk of arcing between phases. The use of more than one complete mechanism in a multi-pole circuit-breaker usually presents considerable difficulty, in view of the risk of single-pole tripping, since it is virtually impossible to obtain simultaneous tripping of all poles. In the multi-pole "Lupus" circuit-breaker, this drawback has been overcome by means of a specially shaped contact arm, which ensures that, when one pole trips, the others are bound to follow.

These double- and triple-pole miniature circuit-breakers (a triple-pole model is illustrated) are available in the same standard ratings as the single-pole type, i.e., 5, 10, 15, 30, and 60 A. As in the single-pole type, "universal" terminals are used for cable connections; for bus-bar connection, a screw-on arrangement is available. These circuit-breakers are 4½ in. high × 3 in. maximum projection, the respective widths for the double-pole and triple-pole types being 2 in. and 3 in.

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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

The Development of Refractory Nozzle Blades for use in High-Temperature Gas Turbines.

By T. H. BLAKELEY and R. F. DARLING. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle upon Tyne*, February 8, 1957, pp. 231–252, 18 illustrations.)

THE operating temperatures of gas turbines are dependent on the properties of the blade material. Since the advent of the jet engine, immense strides have been made in the improvement of metallic alloys, and long-life gas turbines can now be designed to run at temperatures up to about 1400°F, although this development is probably nearing its limit. In order to achieve a fuel economy comparable with that of a marine diesel engine, the operating temperature must be raised to something of the order of 2200°F, and this will clearly require cooling of the blades or, alternatively, the use of non-metallic materials.

The existence of high centrifugal stresses in rotor blades facilitates cooling by the thermosiphon principle and at the same time militates against the use of non-metallic materials which tend to be relatively weak in tension. The stator blades, however, offer a promising field for the application of non-metallic materials, and the present paper describes developments which have been carried out over the last eight years. Numerous materials were tested in the laboratory under conditions designed to simulate the stresses and thermal shocks that will be encountered in service. Various methods of manufacturing the required blade shapes were also investigated, and the shapes themselves were modified to some extent, so as to meet the special requirements of the materials. Cascades of blades were tested in a high-velocity gas stream at temperatures up to 2200°F. Several materials were found to have reasonably good thermal shock resistance, and creep strength at high temperature appeared to be the most serious limitation. At least one material has emerged which seems likely to fulfil the necessary requirements. A single-stage turbine embodying refractory stator blades in conjunction with a liquid-cooled rotor is now in course of development.

A Flat Television Picture Tube.

By D. GABOR. (From *Journal of the Television Society, London*, Vol. 8, No. 4, October-December, 1956, pp. 142–145, 5 illustrations.)

THE main interest of the new television tube described in this paper lies not only in its extremely flat shape, which makes it possible to hang it on a wall like a picture, but even more so in its advantages as a colour tube. It is more complicated than the conventional cone-shaped monochrome tube, but is simpler to construct than known colour tubes, with an even greater simplification in the associated equipment. The tube has the shape of a flat glass box, almost square, and its total depth can be made about 3½ in. for a screen with a 12-in. diagonal, and about 4½ in. for a 21-in. screen.

The tube is divided into two halves depthwise by a metal tray which carries the entire electron-optical system and serves at the same time as a magnetic screen. The electrons start vertically downwards from an electron gun behind this screen, with three independently modulated cathodes, one for each colour, but with a common lens system for handling them. The beams pass through an X-deflector system, which deflects them horizontally, then through two trimmer pairs which serve for compensating misalignments, and from these into a reversing lens, which can be considered as a lens of very unconventional design with a curved optical axis which has four electron-optical functions. It converts the plane fan of rays issuing from the X-deflector into another plane fan, but with about four times greater divergence. Moreover, it compensates the over-focusing effect inseparable from electrostatic deflection to such an extent that the beam remains in perfect focus during the scanning of a horizontal line, although the divergence of the beams after leaving the reversing lens may be as much as 110 to 120 deg. —a hitherto unheard-of large angle in electrostatic tubes.

The beams next pass through a "strong-focusing" electromagnetic lens which bends them back to the vertical, so that the beams perform their scanning motion at the front side like vertical rods. Finally, on reaching a certain level, the beams are bent towards the horizontal and fall on the screen. This final bending and the vertical scanning motion are achieved in an essentially novel way:—In front of the metallic plate acting as a magnetic screen, and at a distance of about ¼ in. from it, there is a "scanning array", which is a system of parallel conductors printed on a flexible insulating base. In the central part of the insulating foil the array consists of about 120 horizontal conducting lines. At the two sides, where the base is bent round in two U-shaped loops, the conducting lines are staggered upwards, their charging and discharging being effected entirely by the electron beam itself. This self-scanning process, although it unavoidably makes the tube more complicated, simplifies the circuit work, as there is no requirement in the set for the usual multi-vibrator running at field frequency. The line-frequency generator is, however, still necessary, but it requires far less power than the line scanner in conventional magnetic television tubes.

Among other problems, one of considerable importance was that posed by the flat screen. If this were made of ordinary annealed glass, it would require the prohibitive thickness of about 1 in. in a 21-in. tube. The difficulty was solved by a prestressing or toughening process which increases the apparent tensile strength of the glass by a factor of at least three or four, but which is capable of further improvement.

Principles and Applications of Spark Machining.

By D. W. RUDORFF. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, February 22, 1957, 13 pages, 18 illustrations.)

THE basic principles underlying the spark-erosion process and its application to machining operations are quite different from the familiar applications of the electric arc. The effect of a spark discharge upon the points of the electrode surface between which the spark passes produces localized melting and partial evaporation of the surface metal. The rapid dispersion of the metal vapour and of molten metal from the point affected can be assumed to be due to the combined action of electrodynamic forces produced by the discharge current and of the mechanical blast effect produced by the expansion of gases caused by evaporation of dielectric and metal, leading to the production of the typical erosion crater.

The spark-erosion process must be visualized as a succession of spark discharges distributed over the surface to be eroded. The spark will pass between electrode and workpiece at that particular point where the electric field strength in the interspace happens to be greatest. On removal of the material from workpiece and electrode at this point by the spark, and the subsequent decrease in

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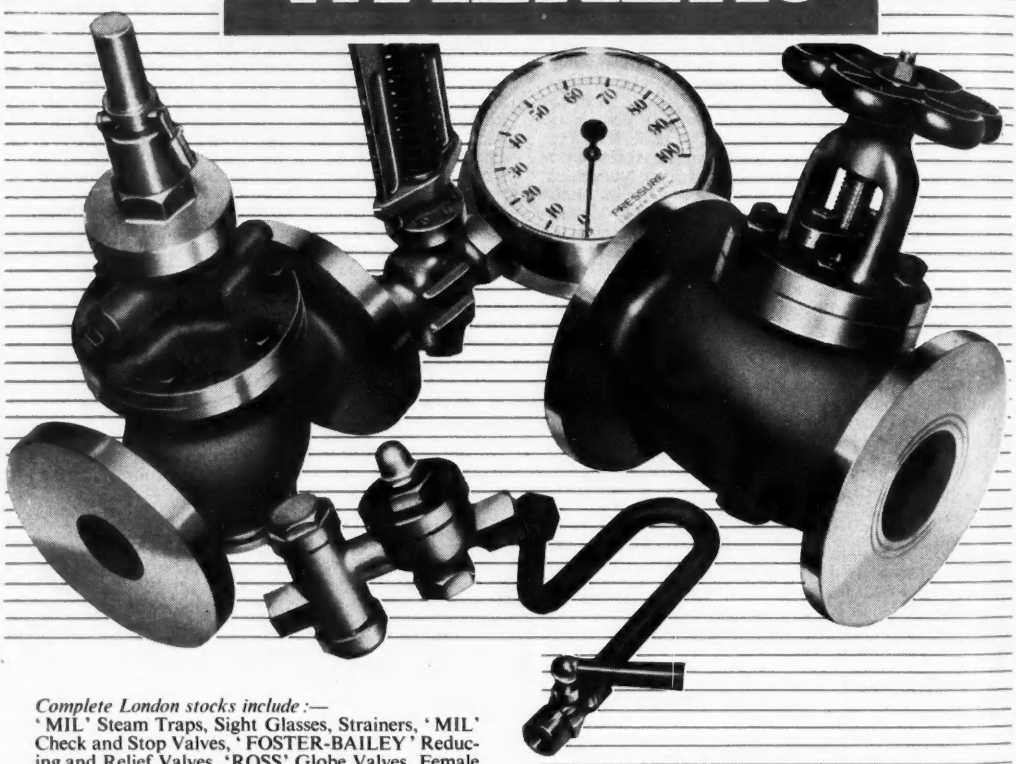

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electric field strength owing to the now greater gap at this particular point, there will exist another point where the electric field strength is now greatest, so that a spark discharge causing erosion at this other point will result. Thus, successive spark discharges wander over the entire surface and cause its gradual removal. The principle of spark-erosion machining therefore consists of the production of spark discharges in rapid succession between cutting electrode and workpiece electrode, the intensity of the spark discharge being determined by the amount of electrical energy supplied from an energy-storing device, such as a condenser.

As each spark discharge produces a pit or crater on workpiece and electrode, surfaces machined by spark erosion have a pitted appearance, the size and depth of the individual pits affecting the roughness of the surface produced. This is governed by spark energy, and by the nature of the workpiece material and dielectric. The dielectric employed in spark-erosion machining is usually paraffin oil, which possesses to a satisfactory degree the various physical, chemical, and electrical properties required.

In this paper, the historical background of electro-erosion technique is briefly outlined and the difference between spark and arc discharges defined. The underlying principle of the relaxation-type spark circuit, as employed in industrial machines, is explained, development trends are discussed, and the various factors bearing upon the efficiency of spark-erosion operations are enumerated. The mechanical features of a typical spark-erosion machine are described, and the range of machining operations for which spark-cutting machines can be designed is outlined. Typical samples of work produced on a commercial unit are described and illustrated, and the properties of spark-machined surfaces are discussed.

The Electroluminescence of Phosphors of the Zinc Sulphide Type.

By P. ZALM. (From *Philips Research Reports, Holland*, Vol. 11, No. 5, October 1956, pp. 353–399, and No. 6, December 1956, pp. 417–451, 42 illustrations.)

THIS thesis deals with various aspects of the electroluminescence of zinc sulphide (Destriau effect), by which is understood the non-thermal conversion of electric energy into light as the result of current passing through solids. A brief survey is given of the theories concerning photoluminescence of ZnS insofar as these are of consequence for electroluminescence, and more particularly those concerning the nature of the fluorescent centres. Various methods of preparation of electroluminescent ZnS powders are treated. In practice, the phosphors are prepared by activating ZnS with Cu in such a way that copper sulphide is formed on the surface.

Details are given of the electrical and optical measurements which have led to the drawing up of a qualitative model, with the aid of which the mechanism of electroluminescence can be explained. For this purpose the influence of amplitude and frequency of the alternating field upon the emittance was studied, as well as the shape of the oscillograms of the emitted light flashes at various suitable voltage shapes. From these oscillograms and from the build-up phenomena occurring when the field is switched on, it appears that a distinction must be made between phosphors where excitation by the field causes ionization of the activators, and those where this does not occur. In the former case the light emission is virtually in phase with the voltage, the moments of maximum excitation and of maximum emittance coinciding. In the latter case, electrical factors cause a shift over a substantial fraction of the period of the field between the moments of maximum excitation and of maximum emission.

In experiments with hexagonal single ZnS crystals activated by Cu it was found that the mechanism of electroluminescence does not differ essentially from that of powders. In single crystals the excitation occurs at the internal barriers, which have a rectifying effect. A relationship could be established between the orientation of the barriers at which light emission occurs and that of the crystal axes.

The observed voltage dependence of the emittance is shown to be due to the presence of a Mott-Schottky barrier. This voltage dependence is connected with the probability that electrons in the conduction band of the crystal are accelerated in an electric field to such an extent that either excitation or ionization becomes possible. A theoretical model has been drawn up for crystals embedded in a dielectric. Here, no direct-current contact with the electrodes occurs, so that the Mott-Schottky barrier extends only over a limited area and depth, owing to polarization effects.

Some experiments are analysed, the theoretical model being tested, for example, as regards delayed light emission and temperature dependence of the emittance. The latter is explained with the aid of the model ; the relation between the local field in the barrier and the strength of the applied field is determined by the presence of electron traps and the space-charge density in the barrier. Finally, a study is included of the energy efficiency of electroluminescent phosphors.

A Simplified Method of Determination of the Specific Heat of a Liquid in an Electric Calorimeter.

By F. KRUPKA and Z. HORAK. (From *Czechoslovak Journal of Physics, Czechoslovakia*, Vol. 6, No. 6, December 1956, pp. 612–619, 2 illustrations.)

WHEN determining the specific heat of a liquid in an electric calorimeter, it is practically always necessary to correct the final reading of the increase in temperature of the liquid in the calorimeter. Thus, the calorimeter and its surroundings are taken into consideration in the exchange of heat, and this correction is usually determined by observing the time dependence of the calorimeter temperature, not only during the measurement itself, during which a known amount of heat increases the temperature of the tested liquid, but also before and after. The entire measurement is thus divided into three parts and takes three times as long as the experiment proper. This is particularly disagreeable when studying the dependence of the specific heat of a liquid on the temperature since, with sufficiently closely chosen steps, the measurement takes too long and also the evaluation of the measured values is rather tedious. An attempt was therefore made to determine the specific heat solely from the time dependence of the calorimeter temperature when heat is supplied in the form of Joule's heat, i.e., without determining the course of the temperature before and after the measurement proper. In this paper, two methods of determining specific heat in this way are described. One of these methods, based on a comparison of the time dependence of the calorimeter temperature after heating two different liquids, one of which has a known specific heat, seems to be particularly suitable for studying the dependence of the specific heat on the temperature. The evaluation of the measured values is based on the same simplifying assumptions as all known methods of determining the temperature correction, i.e., (1) all exchange of heat between the calorimeter and its surroundings, including radiation, is governed, for fairly small temperature differences, only by Newton's law of cooling; (2) the temperature of the surroundings of the calorimeter is constant ; and (3) the temperature of the liquid and the inner walls of the calorimeter with sufficiently intensive mixing and slow heating of the liquid is the same at every point. In addition, formulae are given for calculating the coefficients for the parabolic interpolation of the calorimeter temperature as a function of time, on the assumption that the time measurements are equidistant.

Evaluation of the results of measurement is very simple when graphic procedures are used, and permits the rapid determination of the dependence of the

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measured specific heat on the temperature, at least approximately, eliminating the tedious and lengthy procedure of measuring in steps normally used and determining the temperature correction. It would therefore appear that this simplified method is especially suitable when determining the temperature dependence of the specific heat of a large number of liquids ; furthermore, it permits the use of automatic temperature recording, provided that this is sufficiently accurate.

Transistorized Television Cameras using the Miniature Vidicon.

By L. E. FLORY, G. W. GRAY, J. M. MORGAN, and W. S. PIKE. (From *RCA Review, U.S.A.*, Vol. 17, No. 4, December 1956, pp. 469–502, 19 illustrations.)

THE development of a highly sensitive ½-in. diameter Vidicon, together with recent transistor developments, has made it possible to design television cameras of extremely small size and low power consumption. Transistor video amplifiers with a bandwidth of 8 Mcs, or more, and with satisfactory input noise characteristics have been designed. The low power required for deflection of the beam in the ½-in. Vidicon makes deflection with small standard transistors quite easy.

As described in this paper, an experimental closed-circuit camera has been built which weighs only 3 lb and consumes about 3 W of power. The output is a modulated 60-Mcs signal, which can be connected to the antenna terminals of any standard receiver.

The camera may be powered by an internal a.c. supply or by batteries. A 1-lb silver-alkali storage battery will operate the camera for five hours. Sensitivity is greater than standard 1-in. closed-circuit cameras and resolution is limited by the bandwidth of the receiver.

In another version, a completely portable pick-up station, capable of picking up a scene and relaying it on a 2000-Mcs carrier to a base station up to half a mile away, has been built. This unit, consisting of camera, synchronizing generator, transmitter, and monitor, completely transistorized except for the transmitter itself, weighs 20 lb, including batteries for 5 hours operation.

These two units show that existing transistors make it possible to obtain in such equipment an operating performance which cannot be achieved with vacuum tubes within the same limitations of weight and power. It is also of interest to note that, except for the pre-production drift transistors used in the video amplifiers, commercially available transistors could be used in each socket.

The Economics of Plant Renewal and Replacement.

By C. W. GRIFFITHS. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, February 8, 1957, 16 pages, 7 illustrations.)

WITHIN the framework of the drive to reduce machining and handling time, the immediate causes for plant replacement fall into three definite groups, i.e., (1) wear and tear, where machines are physically worn out, resulting in breakdowns, poor quality, excessive maintenance, and premature overhauls; (2) obsolescence of machines; and (3) obsolescence of methods. In addition, it cannot be overlooked that human factors must also be taken into consideration, e.g., the health and safety of operators, the skill and effort demanded, and labour's reactions to new methods.

An attempt is made in this paper to draw attention to the principal factors bearing upon the economics of plant renewals. It should be noted that no simple formula exists, or is ever likely to exist, to replace the judgment and experience of engineers, and that, however many statistical data are adduced in support of plant selection, the imponderables remain imponderable. The future trend of product designs, pending changes in material forming techniques, the development of feed-back control and automatic gauging, the intangible benefits associated with an improved flow of work, and many other problems present a continuing challenge.

Three main conclusions are drawn, as follows:—

(1) With the ever-increasing rate of technological progress in machine-tool design, in the improvement of production methods, and, above all, in the development of new materials and processes, the type-for-type replacement of plant on an age or wear-and-tear basis is steadily giving way to replacement by improved or different machines which are able to reduce machining or handling times. The advantages and savings to be derived from the higher productivity of these new machines progressively justify the displacement of machines which may still be serviceable but technically obsolete.

(2) This displacement of age by other economic factors must be fully and faithfully reflected in depreciation policy, to guard as carefully as possible against losses arising from obsolescence. Responsibility for bringing this to notice must rest largely with engineers.

(3) If adequate funds are to be provided for the replacement of plant at ever shorter intervals, higher rates of utilization become increasingly important. As the span of life of a machine diminishes in years, so must its effectiveness increase.

The Time-Temperature Dependence of Austenitic Stainless-Steel Welded Joint Components.

By J. HEUSCHKEL. (From *The Welding Journal, U.S.A.*, Vol. 35, No. 12, December 1956, pp. 569s–581s, 24 illustrations.)

AUSTENITIC stainless steels tend to retain their tensile strength at elevated temperatures. The short-time and long-time mechanical properties of such as-furnished base metals, of the welding heat- and strain-affected zones of the base metal, and of the as-deposited weld metals are not always identical at any one temperature. The yield strength of the rapidly cooled weld metal is usually higher than that of the base metal. An important factor in mechanical structural performance is the manner in which these three components of the welded joints, having similar compositions but non-uniform properties, respond as a unit to non-uniformly applied stress and strain under the imposed orders of temperature and time.

Experience with some of the austenitic-matrix type of Cr-Ni steels has suggested the need for a re-evaluation of the characteristics of these and other high-temperature alloys for applications in the welded condition. The existing metal-processing procedures are also open to re-evaluation. The materials involved were usually developed for use in the unwelded condition under corrosive environments at normal temperatures.

These base metals may be brittle over 2450°F in some instances, i.e., just under the melting temperature. They may also be embrittled after having been recooled from 2450°F or above. Narrow zones of base metals adjacent to all-metal arc welds are exposed to such high temperatures for brief time intervals. Another short-time temperature zone in which brittleness often exists, particularly in as-deposited weld metals, is between 1700 and 1900°F. Between this zone and the 2450°F to melting-point zone the metals may be ductile.

The as-welded metallurgical structures may become unstable with time at temperature. Austenitic steels under load at high and medium temperatures tend to decrease in capacity to resist stress and strain with increasing times to rupture. Phase changes, under the impetus of temperature, time, and stress, can cause nominally ductile alloys to become fully brittle at high, intermediate, or room temperatures. This introduces the opposite and seldom-recognized extreme problem; some of the welding difficulties in austenitic matrix materials arise from cold cracking, for example, in maltreated castings.

The purpose of this paper is to enumerate and illustrate the several phenomena involved. A series of corrective procedures is suggested for existing materials. The long-range future solution lies in the controlled processing of high-temperature alloys specially designed for welded applications. Precision control of welding is also necessary.

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This tapping machine uses up to 12 taps, was formerly equipped for flood cooling and lubrication. Parts coming from the machine were so covered with oil that they had to be drained and wiped before the next operation. Coolant splashing over operator and floor resulted in bad working conditions. After installing Spray-Lube, parts were no longer covered with oil, and the eliminating of draining and wiping increased production speed by as much as 30%. In addition, working conditions are cleaner and safer, and a substantial saving in cutting oil consumption is effected.

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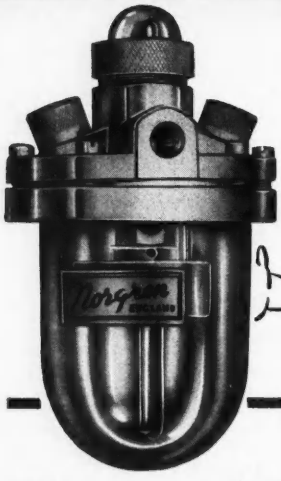

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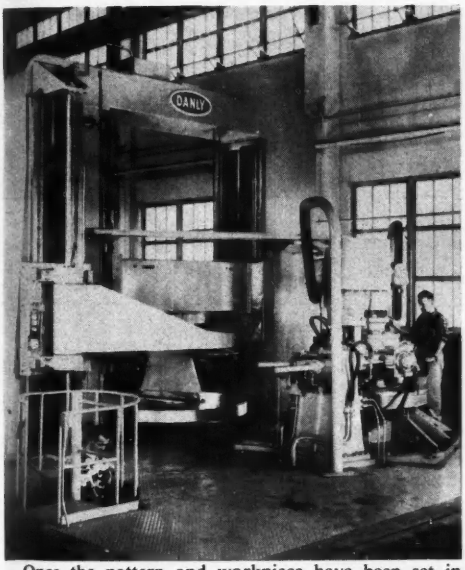
New Materials, Processes, and Equipment

150-TON AEROFOIL MILLING MACHINE

Aerofoil milling machines are essentially machines for duplicating in metal a complex curved shape generated by tracing a prepared pattern. In the Danly aerofoil milling machine, developed and constructed by Danly Machine Specialties, Inc., of Chicago, Ill., a wooden pattern is mounted vertically on a circular revolving table. Two large tracer wheels are held in contact with the pattern and, as the table revolves, the relative motion of the tracer wheels is transmitted to two cutters. These cutters are positioned against the metal blank to be machined, the blank also revolving at the same speed as the pattern. A general view of the machine is illustrated, in which, between the uprights, can be seen the revolving table, the wooden master, and the follower wheels.



Once the pattern and workpiece have been set in position, the action of this 150-ton machine, which is stated to be the largest device of this kind ever constructed, is entirely automatic. It is capable of machining shapes 18 × 18 × 96 in. long, or 8 × 26 × 96 in. long, and the mechanism for holding the metal blank can exert an upward thrust of 8500 lb. Both pattern and workpiece are mounted vertically, as distinct from previous aerofoil milling machines of horizontal design, so as to eliminate any bending which might result from the weight of the metal blank being shaped. The machine has a height of 17 ft above floor level, but requires a sub-floor space of 25 × 25 × 15 ft high, with a smaller pit 6 ft in diameter and 8 ft in height. This pit accommodates the mechanism for the turntable on which the workpiece rides.

Seventeen electric motors are required for operating the machine, of which two spindle motors of 75 hp each are used for driving the metal-cutting tools. The other motors are used for turning the table on which the pattern is mounted, for providing lubrication, for pressurizing the complex hydraulic system, and for furnishing cooling, where necessary, the total motor horsepower being about 425 hp.

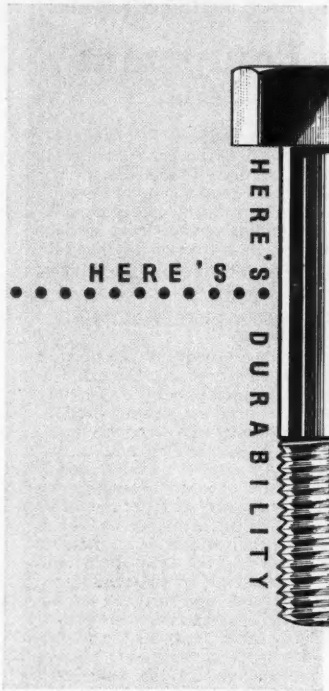
A wide range of flexibility enables the machine to work in various materials. For cutting alloy steels, a speed range of 78 to 785 fpm is available ; for aluminium alloys, speeds between 314 and 3140 fpm can be obtained, in all cases with a working accuracy of 0·004 in. over a 24-in. chordal length and with a good quality of finish.

The primary advantage of the new machine is its ability to produce in one milling operation an aerofoil shape of complex curvature in a fraction of the time required to produce similar shapes by conventional machine-tool and hand-work methods.

SEMI-AUTOMATIC METAL-ARC WELDING PROCESS

A new process for the manual welding of carbon steel is announced by the Linde Air Products Company, a division of the Union Carbide and Carbon Corporation, U.S.A. This semi-automatic metal-arc welding process, designated " Unionarc " welding, uses a continuously fed bare wire, a powdered magnetic flux, and carbon dioxide gas, the flux being carried to the welding nozzle by the carbon dioxide gas stream and surrounding the welding wire as it is fed from the contact tip of the torch. When welding current is flowing, a magnetic field is established around the extended portion of the welding wire. The flux is attracted towards the exposed wire and coats it. As the wire is directed into the weld puddle, the flux melts, refining the weld metal and shielding it from atmospheric contamination. The carbon dioxide flowing from the torch nozzle also helps to shield the molten metal and the arc. This open-arc characteristic of Unionarc welding permits excellent visibility of the weld zone, permitting welds to be made manually in any position with speed, economy, and quality.

Welding speeds are 50 to 100% higher and total welding costs are between 20 and 50% less than those obtained with covered electrodes. The process produces high-quality welds, even when moderate amounts of rust, scale, and moisture are present, as well as when there are minor gaps. Welds in carbon steel develop an ultimate tensile strength of 75,000 to 85,000 psi and a yield strength of 65,000 to 70,000 psi. Welds are characterized by soundness and a minimum of undercutting. The constituents of the flux lower the surface tension of the weld puddle, improving weld surface contour. At the same time, the flux thermally insulates the weld metal from the atmosphere, thus lowering its cooling rate. The thin skin of fused flux comes off easily and, in addition, greater and more uniform weld penetration than that obtained with covered electrodes is provided. Furthermore, flux flow and weld penetration can be adjusted to meet joint requirements and welding limitations. The



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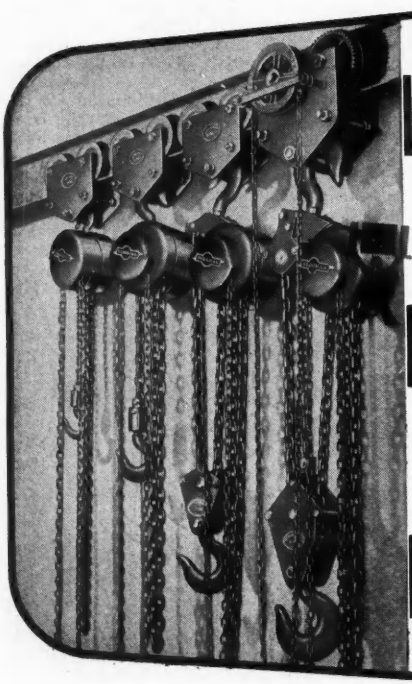

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illustration shows a completed weld in $\frac{3}{4}$-in. plate, and demonstrates the excellent appearance of the joints produced by this process.

Direct-current reverse polarity is preferred. At present, $\frac{1}{16}$-in. diameter and $\frac{5}{64}$-in. diameter welding wires are used. With the former, welding currents are usually between 350 and 450 A while, with the latter, welding currents range usually from 125 to 250 A. The use of a constant-potential d.c. power is preferred generally, although a conventional power supply can also be used.

Because of its general availability and economy, carbon dioxide is an excellent flux-conveying and shielding gas. In all probability, the most widely used applications of Unionarc welding will be in downhand-position welding with $\frac{3}{32}$-in. diameter wire. However, $\frac{3}{64}$-in. diameter wire is suitable for welding in all positions, i.e., flat, vertical, and overhead. Operator skill requirements are less than with covered electrode welding.

214-MVA HYDROGEN-COOLED TURBO-GENERATOR WITH SPECIAL RAILCAR FOR TRANSPORTATION

It is announced by Brown Boveri & Cie., of Baden, Switzerland, that they have recently effected delivery by rail to Germany of a new 214-MVA, 3000-rpm, hydrogen-cooled turbo-generator, the largest generator of its kind so far constructed by this Company.

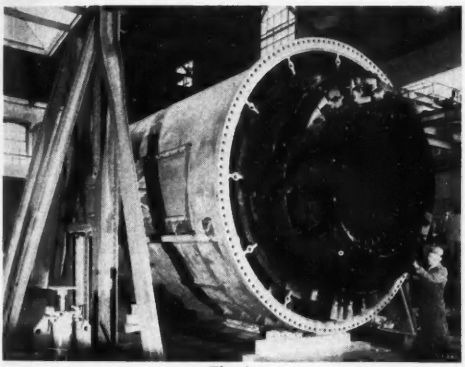


Fig. 1.

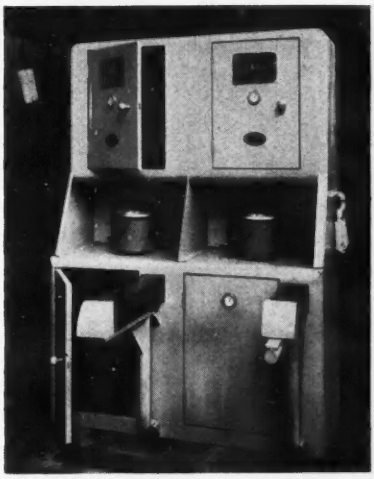
The new generator will deliver 150 MW with a power factor of 0·7, the nominal voltage being 10·5 kV at a frequency of 50 cps. Some idea of the size of this machine can be gained from Fig. 1, which shows the stator, weighing 206 tons, during final assembly. The rotor and shaft are approximately 34 ft in length, the diameter being about 3 ft 7 in.

With generators of this size and weight, transportation problems are inevitable, all the more so because stators of this type should preferably be sent as one complete unit. With this particular unit, therefore, a special railcar, with nine axles at each end, was designed and constructed in collaboration with the Swiss Federal railways, the stator being suspended as shown in Fig. 2. Transportation problems of this kind are likely to become even more acute, owing to the increasing demand for larger and larger generators of this type. In this connection, it is stated that this special car will make it possible to transport stators for generators up to 300 MVA.

Fig. 2.

MOP-DRESSING CABINET

In the addition of abrasives to mops or "bobs" made of felt, leather, cork, etc., the equipment normally used comprises separate units, i.e., emery troughs, glue-pots and heaters, and curing and drying cabinets. However, with the mop-dressing cabinet announced by A. E. Griffiths (Smethwick) Ltd., of Birmingham, all these requirements are combined in one compact assembly. With these cabinets, the mops can be renewed at any time with the required abrasive for any operation, i.e., ranging from fine grades for jewellery to a coarse emery for cutting, with a wide intermediate range for all polishing, buffing and scurfing operations.



The size of the two-compartment cabinet is 4 ft 9 in. × 2 ft 3 in. × 6 ft. 3 in. high. For steam heating the required pressure is 50 psi, and for electric heating the power required is 6 kW, with 600 W for the glue-pots.

MILLING CUTTER WITH MICROMETER ADJUSTMENT

Designed to eliminate the time-consuming operation of adjusting interlocking cutters to the desired dimension, an adaptation of the EUCO micrometer spacing collar used for gang-milling work is announced by EUCO Tools Ltd., of Kingston, Surrey.

A special type of micrometer spacer has been designed to fit between a pair of interlocking cutters, the outer collar of the micrometer spacer being produced with a fine-pitch gear on the periphery, as can be seen in the enlarged illustration of hole (A) on the side face of the milling cutter. A key (B) is provided with teeth of similar pitch, so that, when inserting it into hole (A), it will mesh with the geared outer collar. In order to alter the width of the cutter, all that is necessary is to turn the key in a clockwise direction to increase the width, or anti-clockwise to decrease the width. The key is machine-divided in such a way that each division represents a movement of 0·0005 in., a complete turn representing a movement of 0·004 in. The provision of this fine and easy control makes it possible to adjust the width of the cutter to precision limits in a few seconds, without any need for dismantling the arbor. These new interlocking cutters

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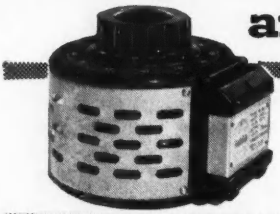

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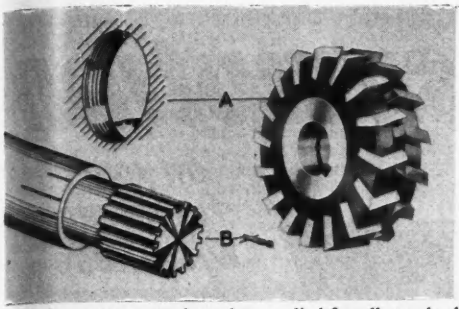
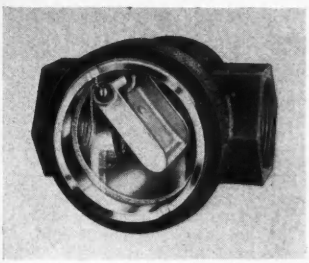


with micrometer control can be supplied for all standard arbors. The minimum width of the inserted-blade type of cutter is 1¼ in., expanding to 1⅝ in.

The same principle is being applied to the solid type of interlocking cutters, and it is anticipated that these will be available with a minimum width of only ½ in.

VANE-TYPE FLOW INDICATOR

The new Bowser Fig. 811 sight-flow indicator announced by Liquid Systems Limited, of Croydon, Surrey, is a single-window, vane-type indicator for use with clear or translucent liquids, and is ideally suitable, among other applications, for use in cooling-water lines to transformers, jacket-water lines for diesel engines, oil lines to hydro-electric turbines and generators, and steel-mill machinery and other equipment.

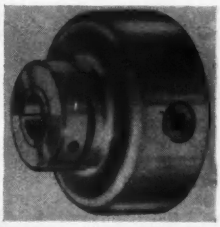


The vane, which is clearly visible through the glass, is spring-actuated, assuming a position at right angles to the centre-line of the pipe when there is no flow, and moving at an oblique angle when liquid is flowing. The position of the vane thus provides an approximate indication of the quantity of liquid moving through the pipe. These indicators can be supplied for pipe sizes of ¾, 1, 1¼, 1½, and 2 in. and with springs of varying tension, permitting their use on either vertical or horizontal pipe-lines. Furthermore, they are so designed that flow may be either from right to left, upwards or downwards.

GEAR-OPERATED DEAD-LENGTH SPINDLE-NOSED COLLET CHUCK

Conforming with standard practice by being adapted for mounting on the spindle-nose of any machine by means of the usual type of backplate, the " Precis-grip " improved gear-operated dead-length spindle-nose collet chuck, announced by W. Compton Cope & Co., of Coventry, is a high-precision unit, featuring axial location of the collet, extremely powerful grip, and robust construction.

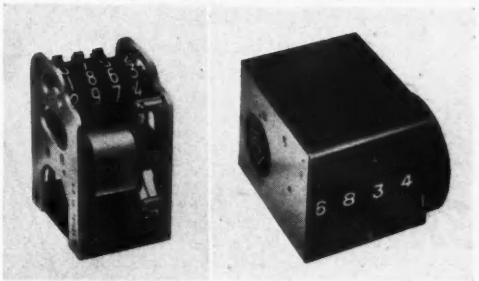
The body of the chuck has a central bore carrying a sliding cylindrical sleeve having a tapered bore at the outer end, and this in turn carries an orthodox collet. The sleeve is prevented from rotating in the body, but is capable of an axial sliding movement. The rear external end of the sleeve has a special helical screw-thread and this is engaged by the bore of a bevel crown-wheel, similarly screw-threaded. The crown-wheel is driven by a much smaller bevel pinion, in a manner similar to that of a scroll-chuck, thus providing a very powerful grip, facilitating the use of tungsten-carbide tools at high operational speeds and pressure. The collet is axially located to give dead-length working in all applications; consequently, any diametral discrepancies in tolerance encountered in a batch of workpieces will not affect the relative position of the tooling from the face of the collet, where length-working is important. Furthermore, since there are no tubes or other mechanisms to obstruct the spindle bore, the full capacity may be used. The collet is mechanically released when the chuck is opened, and there is no tendency for it to wedge, no matter how tightly it has been gripped.



This improved chuck is more capable than ever of performing the functions associated with this type of unit, e.g., for holding externally, as in bar work and second-operation work, and for dead-length disc-facing and boring. Similarly, it is also eminently suitable for holding externally on tubular components, sleeves, etc., and for holding internally, with the aid of an expander and slitted sleeve, e.g., for the width-grinding of gears and for all similar operations requiring precise end-location with respect to the tooling or wheel-edge.

LIGHTWEIGHT HIGH-SPEED ELECTRO-MAGNETIC COUNTERS

Designed for operation where weight is of vital importance, the new range of lightweight high-speed electromagnetic counters announced by Counting Instruments Limited, of Boreham Wood, Herts., is eminently suitable for use in airborne instruments such as cameras, fuel meters, fatigue meters, and recording accelerometers.

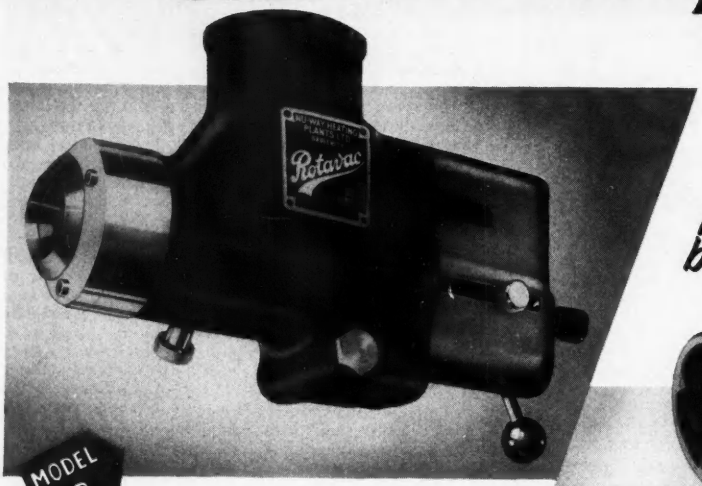


Of these counters, type 54/4 (left of illustration) comprises a series of moulded number-wheels and pinions, giving a display from 0000 to 9999, the assembly being driven from a balanced escapement mechanism of very reduced weight, set in jewelled bearings and energized by one or more electromagnets spaced around a common armature. The armature-to-pole gaps are less than 0·002 in. and are held to close limits, ensuring a highly efficient magnetic circuit. The operational voltage is 22 to 29V d.c., and the counter will operate on pulses of 10 millisec at a maximum rate of 37 per second. Owing to the construction of the mechanical assembly, the counter will not fail under severe mechanical shock, and has been subjected to 7*g* in two directions without failing to maintain an accurate count. The type 54/4 counter, which can be supplied for plug-in connection or with flying leads, weighs only 1·1 oz. and occupies less than 1 × 1⅝ × 1¼ in., so that it is about 5% of the weight and 25% of the size of conventional counters.

The type 52/4 (right of illustration) is similar to type 54/4, except that it is provided with a manual reset, the present speed being limited to 16 counts per second.

Cut OIL consumption

on your furnaces with these **ROTAVAC** proportioning burners



assure

1. *Greater fuel economy.*
2. *Most accurate control of combustion and temperature.*
3. *Better heating uniformity.*

eliminate

1. *Guesswork on air-oil ratios.*
2. *Wide variations in temperature.*
3. *Highly trained burner supervision.*
4. *Production variations and losses.*
5. *Waste of fuel.*
6. *Smoke.*
7. *Low flame instability.*

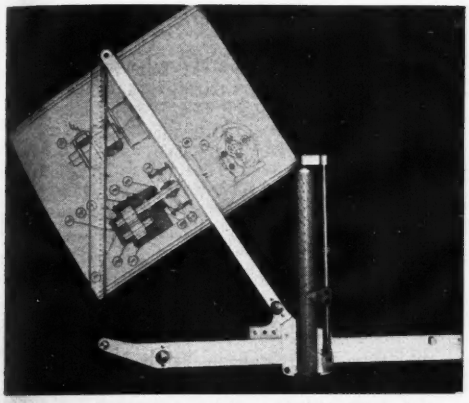
For new installations—Rotavac burners Type PR. Three models, nine nozzle capacities (from 3 imperial gallons/hr. maximum to 17 imperial gallons/hr. maximum at 25" w.g. air pressure). For existing Rotavac installations, where suitable—Rotavac conversion inner assemblies type WPR. Four models to convert standard Rotavac models W, W2, W3 and W4 without alteration of pipework.

Nu-way

NU-WAY HEATING PLANTS LTD. (BOX 669), DROITWICH.
And at London, Manchester, Glasgow, Belfast, Newcastle, Dublin, Bristol.

INSTRUMENT FOR PRODUCING PERSPECTIVE DRAWINGS

Manufactured by The Perspectograph Corporation, of New York, the " Perspectograph " is a simple instrument which can be attached to any drawing board by means of drawing pins, and which is designed to operate on the principle of cylindrical panorama perspective. By means of a calibrated sweep arm and an abacus chart of curves, it enables the user to translate orthographic into perspective drawings merely by plotting perspective points and connecting them. All the construction work formerly required in the production of perspective drawings, such as the location of vanishing points and the drawing of construction lines, is eliminated.

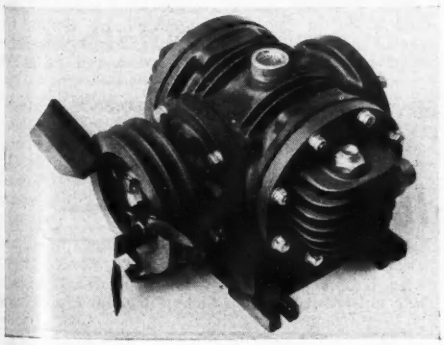


The new instrument enables semi-skilled draughtsmen to execute swiftly and accurately even the most difficult perspective drawings, and is stated to cut the time required for this kind of work by as much as 50 to 70%.

TWIN-CYLINDER DIAPHRAGM COMPRESSOR

A new twin-cylinder diaphragm compressor, capable of continuous operation at pressures up to 50 psi, has been developed by the Hymatic Engineering Co. Ltd., of Redditch, Worcs. This unit should find many applications where a supply of clean air is essential, particularly in the food and brewing industries and in the pressurization of radar and electronic equipment.

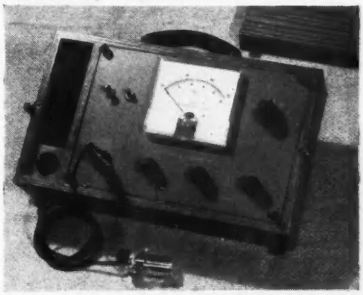
In this new unit, designated the DP. 14, multi-ply high-temperature neoprene diaphragms laminated with nylon are used to provide contamination-free air. Unlike the smaller Hymatic compressors, the DP.14 is also suitable for closed-circuit applications, as both delivery and suction valves are positioned on the same side of the compressor diaphragm. These valves, which are of the simple stainless-steel reed type, are identical. Maximum diaphragm life is obtained by imparting a straight-line motion to the central connecting point of the diaphragm, and this has been achieved in practice by the use of a scotch crank and slipper mechanism. The large bottom end and main bearings are lubricated by the normal splash system, an additional advantage being the considerable heat dissipation from the back of the diaphragm through the oil with which it comes into direct contact. A fan is also fitted to the V-belt pulley, so as to direct a stream of cooling air flow across the finned crankcase and cylinder heads. Aluminium alloy is used for both the crankcase and cylinder-head castings, and cast iron and phosphor-bronze for the scotch crank and slipper mechanism. Ball and roller bearings are employed on the high-tensile steel crankshaft, the size of all bearings being sufficiently large to permit continuous operation over long periods.



Free-air delivery at 1500 rpm ranges between 7 cfm at 45 psi and 9 cfm at 10 psi, the horsepower requirements for the belt drive not exceeding 1·5 hp. If desired, a clutch or venturi-type unloader can be fitted for starting against load.

IMPROVED THERMISTOR RADIOMETER

An improved wide-range thermistor radiometer for the direct measurement of surface temperature is announced by the Williamson Development Co., Inc., of West Concord, Massachusetts. The instrument enables relative or absolute temperature readings to be taken from a wide variety of surfaces, including operating equipment, human or animal skin, building walls, and liquids, while sky and ground temperatures for environmental studies can also be determined. An important feature is that the temperature of moving surfaces can be measured, as actual contact with the surface being measured is unnecessary, temperature readings being made at a distance by directing the radiometer at the object. Measurement of the energy radiated is based on the Stefan-Boltzmann law for black-body radiation.



The radiometer consists of a temperature-detecting head, a circuit for amplification, and a reference black-body for compensation of ambient temperature. Accurate operation over a wide ambient-temperature range is afforded by a self-compensating feature of the thermistor bridge circuit contained in the head. A flexible cable carries information from the head unit to the amplifying circuit, and temperatures are indicated on a meter calibrated in degrees. The head aperture is approximately $\frac{3}{8}$ in. in diameter and has a 20-deg. field of view, permitting selectivity in the measurement of distant objects. The use of sensitive, rapid-response thermistors allows quick scanning of surfaces, measuring temperature differences as small as 0·1°C. Radiometer metering circuits provide full-scale readings, of 10, 30 and 100°C above or below ambient temperature.

The improved model features a modern plastic-case meter with a knife-edge pointer for better readability of both scales. The new meter has higher sensitivity, permitting more inverse feed-back in the vacuum-tube circuit to improve stability. The higher damping characteristics reduce pointer overshoot. The head has been redesigned to prevent zero shift due to relative motion of its parts.

INSTRUMENTS, ELECTRONICS & AUTOMATION

EXHIBITION

Grand Hall, Olympia, London · 7-17 May, 1957

(10 a.m.—6 p.m. daily · Open until 9 p.m. Fri. 10th & Wed. 15th May)

Over two hundred leading British manufacturers engaged in the design and production of instruments, electronic and automation equipment, are taking part during May in what is expected to be the most significant post-war exhibition.

PROMOTING THE EXHIBITION ARE:—

- The British Electrical and Allied Manufacturers' Association
- The British Industrial Measuring and Control Apparatus Manufacturers' Association
- The British Lampblown Scientific Glassware Manufacturers' Association
- The Drawing Office Material Manufacturers' and Dealers' Association
- The Scientific Instrument Manufacturers' Association of Great Britain

A Conference will be held throughout the period of the I.E.A. Exhibition. Further information regarding both conference and exhibition will be gladly supplied by the organisers:

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Fluvent
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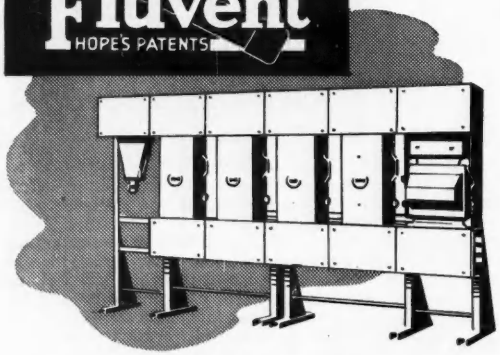
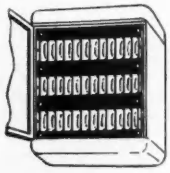


FUSES AND SWITCHGEAR

Energy distribution through Fluvent switchgear and Aeroflex fuses ranges from the industrial switchboard to the domestic House-Service cut-out, an interesting newcomer to the range being the Cabinet Style streamlined Distribution Board, available in a variety of sizes.



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NEWS OF THE MONTH

PERSONAL

Mr. G. W. Hall, a Vice-Chairman and Managing Director of the Fairey Aviation Company Ltd., has been appointed acting chairman following the death of Mr. Roland T. Outen.

Mr. C. W. Bigg has retired from the Board of Ley's Foundries and Engineering Co. Ltd.

Mr. F. Whitehead has relinquished his appointment as General Manager with the Chatwood Milner (Speke) Ltd. organization and has been appointed General Manager, metal equipment divisions, at Darlaston and Wrexham with Rubery Owen and Co. Ltd.

Dr. Maurice Cook, formerly Joint Managing Director of Imperial Chemical Industries Ltd. Metals Division, has become Chairman of that division. He has been succeeded as Joint Managing Director by **Mr. St. J. Elstub.**

Dr. J. S. Gourlay formerly Joint Managing Director of the Plastics Division, has been appointed Chairman of the Paints Division.

Mr. J. C. H. McEntee has been appointed Chairman of the Wilton Council of I.C.I. His place as Joint Managing Director has been taken by **Mr. R. E. Newell,** formerly Chief Engineer of the Wilton Council.

Colonel J. P. Hunt has joined the Board of Newton Chambers and Co. Ltd.

Mr. R. C. Heath has been appointed a Director and **Mr. R. E. Parish** an alternate Director of Peto Scott Electrical Instruments Ltd.

Tiltman Langley Ltd., announce changes in the Board of Directors. **L. A. Wingfield, M.C., D.F.C.** is appointed Chairman, **Major H. H. Sykes,** Managing Director, **Marcus Langley, F.R.Ae.S., A.M.I.Mech.E.,** Technical Director, **L. D. Neeves, F.C.I.,** Secretary, and **N. W. Collett.**

Mr. George Holland, of 27 Lainshaw Avenue, Kilmarnock, has been appointed as Scottish Area Technical Sales representative of Newall Group Sales Ltd., Peterborough. A former planning and process engineer with Scottish Aviation Ltd., Prestwick, he has until recently been on the Sales Staff of John S. Young and Co. Ltd., Glasgow.

Mr. A. G. Colston, Technical Adviser (Service), Hoover Limited, and a director of Hoover (Electric Motors) Limited, is to retire from the company at the end of March after more than 33 years service.

Major-General R. E. Urquhart, C.B., D.S.O., has been appointed a Director of Duncan Stewart & Company Limited, the Glasgow subsidiary of Davy and United Engineering Company Limited. He joined Davy-United in an administrative capacity in the autumn of 1955.

Expandite Limited, Designers and Manufacturers of Jointing Materials and Sealing Compounds for over 20 years have now inaugurated a new Technical Development Department. **Mr. J. W. Babbs, B.Sc., A.P.I.,** will be Technical Development Manager and **Mr. A. B. Kozlowski, B.Sc.** has been appointed Chief Development Chemist.

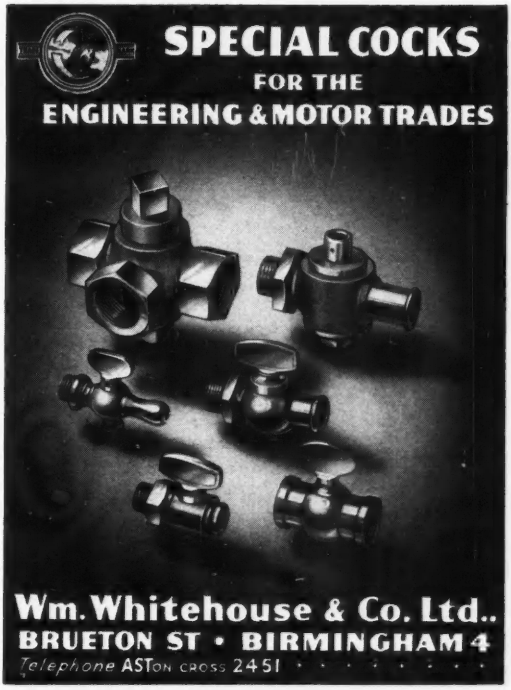
Tecalemit Limited of Plymouth announce the appointment of **Mr. R. F. Brooker** as General Sales Manager. Mr. Brooker joined Tecalemit in 1928, as a Representative and operated in both the Industrial and Automotive field.

Mr. W. R. Edwards, M.I.Mech.E., has retired from the position of Managing Director of John Thompson Water Tube Boilers Limited, after over 50 years of service with the John Thompson Group. For the time being Mr. Edwards is continuing with the John Thompson Group of Companies in a consultative capacity. **Mr. C. J. Howard** has been appointed as Managing Director to John Thompson Water Tube Boilers Limited. Mr. Howard has been with the Company for 31 years, the last 20 years of which he has operated as London Manager and Director.

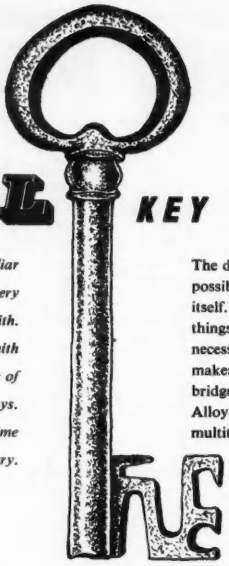
In connection with the opening of the new combined bar and rod mill at Samuel Fox & Co. Ltd., Stocksbridge, the following appointments are now announced:—**Mr. P. Thompson** is appointed Manager of the new department—the bar and rod mill. **Mr. A. E. Hanselman** is appointed Assistant Manager (Rolling), **Mr. L. Long** is appointed Assistant Manager (Warehouse and Treatment), **Mr. A. Crossley** will act in a technical capacity for bar treatment matters, and will be responsible for bringing the section into production. An extension to the company's ingot processing facilities is included in their forward plans, and Mr. Crossley's title now becomes Manager, Steel Treatment Department. **Mr. C. Brooks** is appointed Assistant Manager of No. 1 Melting Shop.

William Beardmore & Company Ltd., Parkhead Steelworks, Glasgow, have pleasure in announcing that **Mr. Hugh R. Byers,** Special Director and Sales Manager, has been appointed a Director of the Company.

Mr. William Hugh Rogers has been appointed Industrial Sales Manager of British Oxygen Gases Limited.



STEEL KEY TO INDUSTRY



Another medieval key of peculiar design, and like No. 16, was very likely made by a local blacksmith. The blacksmith was also a locksmith in those days and made anything of steel, from Knightly Arms to keys. This key was probably made some time during the 15th Century.

The development of steel made possible the growth of civilisation itself. For steel is the key to the good things of life as well as to the necessities; as essential to the maker of the precision watch as to the bridge-builder. Hallamshire high-grade Alloy and Carbon steels serve a multitude of industries in many ways.

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The MG12 is a manually operated machine for accurately grinding small workpieces, where the actual grinding times are short and automatic movements cannot be fully exploited. Useful for either Toolroom or Production work, it can also save money as a basic auxiliary to larger machines.

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WHEEL SPINDLE SPEEDS 2200 and 2500 rpm.
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His Grace The Duke of Northumberland has been elected President of The Institute of General Managers, 86 Eccleston Square, London, S.W.1. Vice-Presidents are the **Rt. Hon. The Viscount Cobham, T.D. (Governor-General designate of New Zealand), Sir Rupert de la Bère, Bart., K.C.V.O.,** and **His Grace The Duke of Rutland.**

Mr. Graham Cooke has been appointed Advertising and Publicity Director of the Solartron Electronic Group Ltd., having been elected a director of Solartron Laboratory Instruments, Ltd.

Messrs. H. Clarke & Co. (Manchester) Ltd., Atlas Works, Patricroft, Manchester, announce the following changes in connection with their Sales Representation. **Mr. R. M. King,** who has been with the Company for a number of years as a Technical Sales Representative, will be responsible for Northamptonshire, Bedfordshire, Cambridgeshire, Norfolk, Suffolk, Essex and Hertfordshire, in addition to sections of the London Area. **Mr. P. G. Robinson,** who has recently joined the staff as a Technical Sales Representative, will be based on Birmingham, covering the Birmingham area, Warwickshire, Worcestershire, Staffordshire and Shropshire.

The following changes in the Board of Directors of Griffin & George Limited, the Laboratory Furnishers, are announced; **Mr. Ronald McKinnon Wood, O.B.E.,** has asked to be relieved of his duties as Chairman of the Company, in view of the important public duties he will assume in the near future as Chairman of London County Council. **Mr. H. R. Bettinson, M.C.,** hitherto Vice-Chairman, will, for the time being, act as Chairman of the Board. **Mr. Norman McKinnon Wood** has been appointed Vice-Chairman and relinquishes his appointment as Managing Director. **Mr. Norman Trepte** has been appointed Managing Director.

The Components Group of The Plessey Company Limited announce the appointment of **Mr. F. C. Loughborough** as Executive Assistant (Sales) to the Group Director, Mr. John A. Clark. Well known in the radio industry, Mr. Loughborough has held several commercial appointments with various Plessey Divisions.

With effect from March 1st, 1957, **Mr. J. Peter Ford, M.A., A.M.I.E.E., C.I.Mech.E., C.I.Mar.E.,** has been appointed to the Board of Associated British Engineering Ltd., as an Executive Director.

To keep pace with the growth of production departments and the services on which they rely, Samuel Fox and Company Limited, of Stocksbridge, near Sheffield are to strengthen their works management organization by appointing a Works Manager (Services). **Mr. H. Morley** will relinquish his present position as Work Study Officer to The United Steel Companies, Limited, in order to take up this new appointment on April 1. He will be responsible under the General Works Manager of Samuel Fox for the following activities and the departments which cover them: fuel, instrumentation, operational research, production control, traffic, and work study and development. **Mr. J. H. D. Kerse** will take over from Mr. Morley as Acting Work Study Officer to United Steel from April 1.

The Heston Group of Companies of 1 Buckingham Palace Mansions, Buckingham Palace Road, London, S.W.1 announce that owing to considerable expansion, **Mr. C. G. C. Thomas** is appointed Sales Manager of Salisbury Precision Engineering Limited for the sale of "Sherpa" Trucks and "Revelation" Optical Projectors. **Mr. C. Chester-Browne** continues as Sales Manager of the Heston Equipment Company Ltd.

Head Wrightson & Co. Ltd. announce that **Mr. R. H. Sturges** (Managing) and **Mr. R. Purnell,** have been appointed to the Board of Head Wrightson Teesdale Ltd. (formerly the Engineering Division of Head Wrightson & Co. Ltd.).

BUSINESS NEWS

To keep pace with the growth and expansion of its business within the United Kingdom, **Burroughs Adding Machine Limited,** is reorganizing its marketing and manufacturing organizations and forming a high-level operating committee to formulate overall policy and coordinate operations. Mr. Reginald C. Cavill, who has been Sales Manager since 1954, has been appointed General Manager in charge of the newly created Marketing Division and will be responsible for marketing operations, marketing accounting, advertising, product promotion and training, service administration, recruiting and management of marketing personnel and market analysis. Mr. James T. FitzGerald, who is Factory Manager of the Company's plant in Strathleven, Scotland, has been named General Manager of the newly created Manufacturing Division, and will be responsible for manufacturing operations in the present Nottingham and Strethleven factories and in the new Cumbernauld factory now under construction

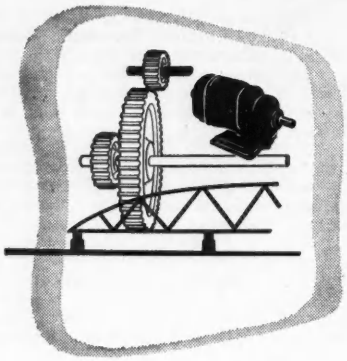
The Head Office of **The Incorporated Plant Engineers** is now 12, The Parade, Solihull, Warwickshire. Tel. Solihull 1111.

Compoflex Co. Ltd., 23-25 Northumberland Avenue, London, W.C.2, have extended their flexibles advisory and manufacturing facilities to include certain forms of rigid tubing by the acquisition of the entire share capitals of Rollo Hardy & Co. Ltd. and Tube Making Machines Ltd.

During the past ten years, Compoflex have built-up what is claimed to be the only comprehensive flexibles service in the world. The extension of this service to include rigid tubing is claimed to be a logical development. Both companies will continue their activities and will operate as independent manufacturing organizations at their 40,000 sq. ft. factory at Blaenrhondda, Glamorgan. The two sales organizations, however, have been absorbed into the parent company's new Rigid Tube Division, although the technical services remain at Blaenrhondda. The export departments have been integrated with the Compoflex Export Division and will thus benefit considerably from the more complete overseas coverage. A large-scale expansion programme is planned for the two companies, including modernization of the Blaenrhondda factory and the installation of new equipment and machinery. A production expansion of 25% for both companies is planned mainly to cope with the expected increase in export orders. Mr. J. C. W. McCallum and Mr. J. V. Klein, the joint managing directors of Compoflex Co. Ltd., hold similar appointments also on the boards of both the newly acquired companies. Three senior executives of Compoflex have been appointed also to the board of Rollo Hardy & Co. Ltd. They are Mr. S. Polkinghorn, general manager (commercial); Mr. W. N. Matts, purchasing manager; and Mr. M. W. Wilson who will be also resident director of Tube Making Machines Ltd.

A new branch office has been opened in Glasgow by **Square D Limited,** to provide effective field coverage throughout Scotland for Square D electrical control gear. With offices already established in London, Birmingham and Manchester, Square D are now able to offer complete field coverage for the whole of Great Britain. Mr. Robert Brodie, who joined Square D last October has been appointed Area Manager. The new offices are at 235 Bath Street, Glasgow C.2. Telephone : Central 3260.

A new Research and Development Division has been established by **The Pyrene Company Limited.** Its function will be to further improve co-ordination between the various fire research, development and experimental activities carried out within the Company. Air Commodore J. A. Hawkings, C.B.E., R.A.F. (Retd), M.I.Mech.E., A.F.R.Ae.S., has been appointed Controller of the new Division.



the keys to industry

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Admiralty, etc.

Negotiations have recently been successfully concluded between **Metalock (Britain) Limited** and **Messrs. Nicol and Andrew Limited,** for the former to represent the latter in selected areas of Britain.

News of still further expansion of the **Consolidated Pneumatic Tool Company's** foreign business is revealed in the announcement that another subsidiary company has been formed, this time in Holland, to cover the interest of their customers in the Dutch Petroleum Industry. The new Company, known as N.V. Chicago Pneumatiek is under the control of the following Directors : Mr. N. Readman, Mr. K. Zeevenhooven, and Mr. R. R. Parker, and the Organization has already commenced activities. For the time being, the day to day management of the new Company will be carried out by Messrs. Zeevenhooven & Co. N.V., from their offices at Keenstraat 32, Rotterdam. Messrs. Zeevenhooven & Co. N.V., are the Dutch Representatives for Consolidated Pneumatic business outside the Petroleum Industry, and they will continue their operations in this capacity. The new Company will have the benefit of adequate stocks of tools and spare parts at their Rotterdam address, as a means to providing a complete sales and technical service in the petroleum field.

Standard Telephones and Cables Limited opened on March 4th, a cable depot and warehouse at 33 Pilcher Gate, Nottingham (Telephone No. Nottingham 52333). Under the management of Mr. R. N. Baylis, this new depot will carry complete stocks of all " Standard " rubber and plastic cables.

The new address of the headquarters and administrative offices of **Stella Lamp Company Limited** will be :— 158/160 Shaftesbury Avenue, London, W.C.2. Telephone : Covent Garden 3031. Telegrams : Stelamp Wescent London.

Due to the continuing expansion of the sales organization of **Midland Silicones Ltd.,** the North Eastern Area Sales Office has moved from its former address to more extensive premises. The Area Sales Manager is Mr. R. Nattrass. The new address is :— 5/7 New York Road, Leeds, 2. Telephone : Leeds 26768. Telegrams : Midsilicon, Leeds.

The Plastics Division of the **Mentmore Manufacturing Company Ltd.** has moved to Stevenage New Town. This is Phase One in the occupation of a large new factory that will eventually bring all branches of the Company under one roof. From 11th February, the new address of the Plastics Division is : Six Hills Way, Stevenage, Herts. (Tel : Stevenage 1701, three lines).

The address of the Southampton Branch office of **British Insulated Callender's Cables Limited** will be, as from 25th February, 1957 : 16/17 Vincent's Walk, Southampton. The telephone number, Southampton 26176/7 will remain unchanged.

Associated British Engineering Ltd. announces the formation of a new subsidiary company, **Newtherm Oil Burners Limited,** which will manufacture industrial and domestic oil burners on a large scale for home and overseas markets. Newtherm Oil Burners Ltd., will be under the chairmanship of Mr. Lawrence Robson.

The British plastics industry had another record production and export year in 1956, it is announced by the British Plastics Federation. Output, which has been more than doubled since 1950, reached about 335,000 tons, an increase of more than 10,000 tons compared with the 1955 total of 324,000 tons. The increase is at a slightly reduced rate compared with 1955, output for 1954 having been 274,000 tons. Thermoplastics materials including PVC, polythene and polystyrene, were again responsible for more than 50 per cent. of the output. Exports of plastics materials alone in 1956 amounted to nearly 98,000 tons, valued at over £26m, a rise of nearly 13,000 tons, valued at over £3m, compared with the 1955 figures, the previous highest. The increase in exports is at a slightly higher rate than in 1955 (1954 exports, over 73,000 tons, value £20½ m.)

A year ago it was announced that an arrangement had been reached between F. H. Lloyd & Co. Ltd. and the American Brake Shoe Company for a joint venture in Great Britain. This has now been implemented by the registration of a new company designated as **Lloyds-Brake Shoe Limited,** with a capital of £100,000. This company is to take over all the share capital of F. H. Lloyd & Co. Ltd.'s wholly-owned subsidiary, Lloyds (Burton) Ltd. The object of this agreement is to operate foundry processes and techniques which are being successfully and extensively used by the American Brake Shoe Company's Engineered Castings and Electro-Alloy Divisions in the U.S.A.

Now occupying a new and larger factory in Purley Way, Croydon are **Weldcraft Ltd.,** manufacturers of gas welding rods and equipment. Formed in 1946, the activities of the company have steadily increased making necessary a move from the old Progress Way works in Croydon.

Cooper & Company (Birmingham) Limited, Felt Manufacturers—Head Office, Brynmawr, Breconshire—established over 100 years, announce that they have acquired the whole of the Share Capital of **James Farrer and Sons Limited,** Devonshire Works, Division Street, Sheffield, with effect from the 1st January, 1957. The new Directors of James Farrer and Sons Limited are all active Directors of Cooper and Company (Birmingham) Limited and the new management will widen and extend the activities of the Company at Sheffield. From 2nd January, 1957, the Board of Directors of James Farrer and Sons Limited is E. F. Bensly, Chairman and Managing; N. W. Hailey (Secretary) ; H. R. Walford.

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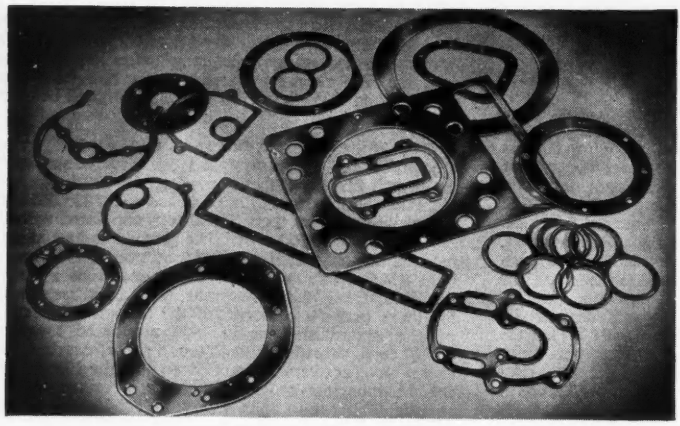

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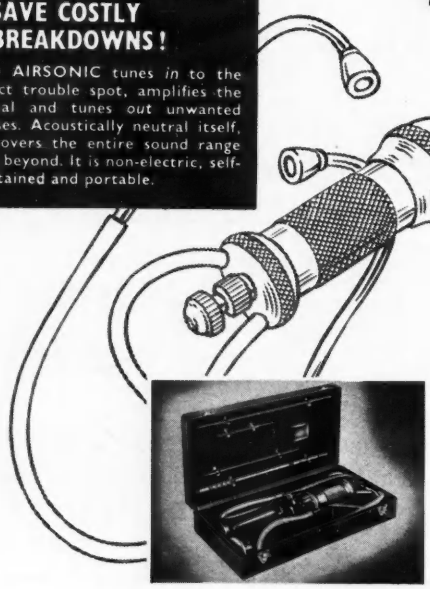

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FB04

INDUSTRIAL PRODUCTS

"Industrial Electronic Equipment" is the title of a new fully illustrated publication released by **Lancashire Dynamo Electronic Products, Ltd.** Copies may be obtained from the company's Works at Rugeley, Staffs.

Greater safety and more compact installations are two of the advantages of using new Combination Starters now being manufactured in Britain by **Square D Limited.** They consist of a Class 8536 line voltage magnetic starter with a new interlocking load-break disconnect switch housed in a single unit. The disconnect switch, which can be fused if desired, is horsepower rated and mechanically actuated by means of a handle on the enclosure cover. Because of their installation as a single unit, there is an appreciable saving in mounting space, wiring and installation cost and the removal from one location to another is considerably simplified.

Fundamental studies of the structural changes in alloy steels will receive a further impetus as the result of the installation of a Siemens II electron microscope at the central research and development department of **The United Steel Companies, Limited.** With this new equipment it will be possible to obtain magnifications of up to 100,000 times.

The Holland-America Line's fleet of transatlantic luxury liners is being equipped with the latest type of Frequency Modulated V.H.F. radio-telephones supplied by **Automatic Telephone & Electric Company Limited,** for use in harbour control and short distance communications. This order coincided with another contract from the **Netherlands Posts and Telegraphs Department** for Frequency Modulated V.H.F. radio-telephone stations at the Hook of Holland. The Netherlands Government intends to establish a chain of similar coastal V.H.F. stations for operation on the international maritime frequencies recently agreed upon at Gothenburg and Warsaw. Under the scheme it is proposed that all port and harbour authorities should in future establish F.M. coastal stations so that it will eventually be possible for ships to use multi-channel.

F. Perkins Ltd., Peterborough, announce that all their diesel engines will operate satisfactorily on mixtures of gas oil (derv) and up to 50% volume of petrol. The company stated that although satisfactory running can be obtained on even higher proportions of petrol, these are not recommended as they involve modifications to the fuel injection equipment. No modifications to the engine or injection equipment are necessary with up to 50%v petrol. Adequate lubrication of the injection equipment is obtained from the gas oil component, but care should be taken to ensure that there is no restriction on the suction side of the fuel lift pump caused by a dirty fuel filter or faulty fuel feed pipe which might lead to vapour locking difficulties.

The first issue of a newspaper-style publication entitled "Prospects" has been published by **Acheson Colloids Limited.** Produced primarily but not exclusively for the benefit of present and potential users of 'dag' Dispersions, "Prospects" will appear periodically at approximately quarterly intervals. The subject matter will include articles on the application and advantages of using 'dag' products, test and technical data, hints on usage, news of new and successful applications and, it is hoped, contributions from industrial users.

A new feature of the Hobrough No. 2. EE. Surface Grinder manufactured by **Modern Machine Tools Limited,** Broadgate House, Coventry, with electro-mechanical clutch, is a variable table feed. This optional extra gives all the advantages of infinite speed variation without the expense and complication of hydraulics. The standard unit gives a table feed from 22 to 32 feet per minute and slight variations on this range can be supplied if necessary.

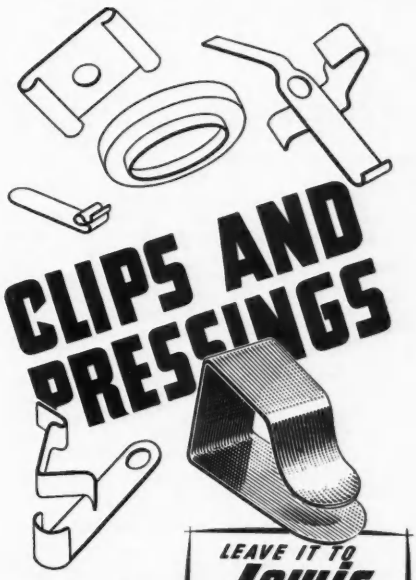
To meet the need for providing machine tools and special purpose machinery with a "built-in" supply of compressed air, a new range of Hydrovane type compressor units is now offered by **The Hymatic Engineering Co. Ltd.,** of Redditch, Worcs.

A loose-leaf manual containing a series of technical data-sheets—forming a unique "text-book" on the use of concrete additives, roof waterproofing pastes, protective paints, mastics, building adhesives and similar products—has been published by **Evode Ltd.,** of Stafford, for the use of architects, builders and contractors. Each sheet gives detailed guidance on the range of uses of various materials, together with full information to enable users to secure the best results in each application.

Tecalemit Limited, manufacturers of lubricating equipment announce that the Bijur range of mechanical pumps is being extended with the introduction of the "M" type Cyclic Lubricator. This lubricator is designed to give intermittent, measured amounts of oil at predetermined intervals. It is available with a range of reduction ratios to suit various operating speeds.

A new carburetter embodying a number of refinements is announced by **The Villiers Engineering Co. Ltd.,** two-stroke and four-stroke engine manufacturers, of Marston Road, Wolverhampton. It is listed as Type S.12 and is suitable for Villiers two-stroke and four-stroke industrial engines of up to 150 c.c. capacity and for Villiers two-stroke motor cycle engines of 98 c.c. capacity.

Russell Newbery & Co. Ltd., of Dagenham, who recently announced increased rating of their diesel marine engines, now report new additions to their range of products. They are now manufacturing a complete range of trailer-mounted, self-contained diesel generator sets covering 3 to 75 kW.



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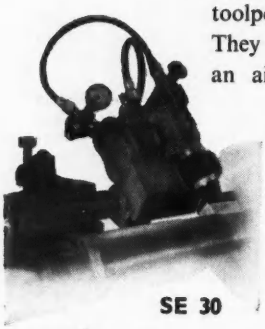
Supfina attachments can be mounted on lathe toolposts for superfinishing any diameter of shaft. They are completely self-contained requiring only an air supply of approx. 80 lb. per sq. in.



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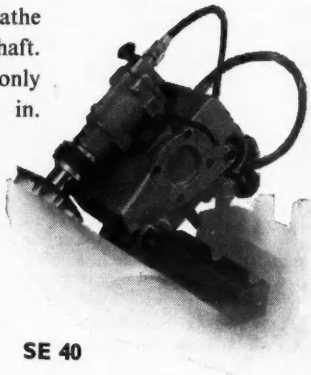
SE 40. Especially robust attachment for finishing rough surfaces and large components.



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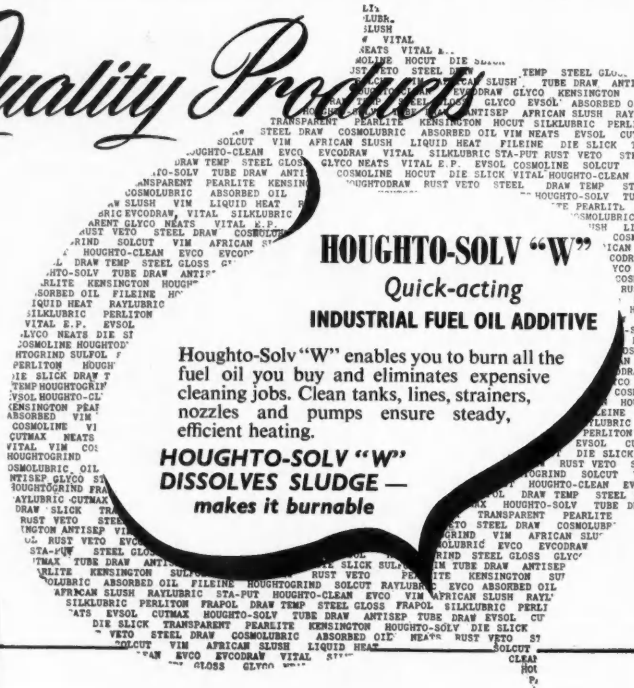

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EXHIBITIONS AND MEETINGS

The British Commonwealth Welding Conference, organized by The Institute of Welding will be held in London and Saltburn-by-the-Sea from the 17th to 29th June, 1957. Information can be obtained from the Secretary (C.W.C.), The Institute of Welding, 29 Park Crescent, London, W.1.

A subject of great importance and interest, " Electricity in the National Economy ", has been chosen as the theme of the ninth **British Electrical Power Convention** which is to be held this year at Eastbourne from 17th to 21st June. The Convention is under the Presidency of Mr. J. Eccles, C.B.E., M.M., B.Sc., M.I.E.E., M.Inst.C.E., M.I.Mech.E., F.Inst.F., Deputy Chairman (Operations) of the Central Electricity Authority. As in previous years an Electrical Exhibition will be held in conjunction with the Convention. This will be situated in the grounds adjoining the Winter Gardens (where all the Convention's business sessions are to be held), and will occupy over 32,000 square feet. It will be officially opened by the President on the evening of Monday, 17th June.

The third annual conference of engineers and others with special responsibilities for standards will take place on Thursday, 9th May. Because of the success of the two previous gatherings of this kind (which were held at British Standards House) this year's meeting will be at Church House, Westminster, enabling many more people to attend. The conference is being arranged jointly by the **British Standards Institution** and the **Institution of Production Engineers.** Mr. H. Stafford, Chairman of the I.P.E.'s Standards Committee, will preside. The conference will provide an opportunity for discussion of the practical application of standards on the factory floor. The agenda will include items on the role of national and company standards ; the development of a coding system for British Standards ; and international standards work. Application forms for tickets may be obtained from B.S.I., 2, Park Street, London, W.1. A registration fee of £1 1*s*. 0*d*. (including the cost of a buffet luncheon) will be charged.

Because of recent International events which have forced several European countries to cancel or reduce their space reservations, the two sections of the **Copenhagen International Fair,** the Commercial and Technical Fairs, are now to be combined in one Fair to be held from 29th March to 7th April, 1957. Space is still available for British manufacturers of all types of consumer and household goods, engineering machinery, precision tools, optical and scientific instruments, metal pipings, tubes, plastic machinery, dairy equipment, diesel engines and office equipment. The Copenhagen Fair is the only exhibition of its type held in Denmark, and will be visited by importers and technicians from all over Denmark and neighbouring countries. Fuller details can be obtained from the official agents in the U.K., Auger & Turner Group, Ltd., of 40 Gerrard Street, W.1.

Following their successful participation in last year's Vienna Trade Fair, the **Birmingham Exchange and Engineering Centre** decided to participate in three important overseas trade fairs in 1957. These are the Leipzig Technical Trade Fair, March 3rd to 14th, the German Industries Fair, Hanover, April 28th to May 7th, and the International Autumn Trade Fair, Vienna, September 8th to 15th. In Hanover the Centre will co-operate with the Board of Trade in the British Government Enquiry Office. They will handle all engineering enquiries received and will distribute literature and other information. At Vienna the Centre will work on the same lines as last year, handling, by arrangement with the Board of Trade, all engineering enquiries received at the British Pavilion. Their stand will distribute literature and display photographs and exhibit certain products. Mr. A. J. Cox, the Centre's Manager will be in personal charge of the Centre's stand in each case.

Early this month **Livingston Laboratories Ltd.** presented, for the first time at any engineering exhibition in the world, an outstanding new Television monitoring equipment. Flown over for the **Television Society Exhibition** by the manufacturers, **Telechrome, Inc., U.S.A.,** the equipment provides a system for continual identification and technical monitoring of a complete Television network during actual transmission. Any technical fault can be immediately identified and positioned by the equipment which is equally suitable for monochrome and colour transmissions. The outstanding advantages are that the monitoring signal does not interfere with the programme content and the greater accuracy of adjustment now possible for studio equipment and receivers.

" Automation in the Smaller Business " is the title of a lecture illustrated by two 25 minute films to be given by Mr. John A. Sargrove, M.I.E.E., M.Brit.I.R.E., M.I.Prod.E., Technical Director of Automation Consultants and Associates Limited, who will address a joint meeting of **The Institute of Commercial and Industrial Managers** and **The Institute of General Managers,** London Branches, in the Charing Cross Hotel, London, on Tuesday, 16th April, 1957, at 7 p.m. (Reception will be from 6.30 p.m. onwards when a Private Bar will be available). This is the third of the series of joint meetings on " The Impact of Automation on Management ". Non-members wishing to attend this meeting should apply for tickets or further particulars to C. J. Hatter, A.C.I.M., A.C.I.S., Hon. Secretary, London Branch I.C.I.M., 38, Chalkhill Road, Wembley Park, Middlesex, telephone ARNold 8863.

The University of Nottingham is planning a residential course on " Nuclear Engineering " to be held at the University from 15th to 21st September, 1957. The course is directed at engineers who are new to this field, and who want a general picture of the outlines, rather than a detailed study. Many of the most eminent authorities in Nuclear Engineering will be taking part, by giving lectures and holding discussions.

The Gauge and Tool Makers' Association will be organizing another composite Stand at the forthcoming British Industries Fair, to be held in The Fair Buildings. Castle Bromwich, Birmingham, from 6th to 17th May, 1957, inclusive. The Stand will occupy a site (C. 413/312) of over 1,000 square feet, and at least 40 of the 336 firms in the Association will be displaying a small range of their manufactures on the Stand together with sales literature. The Association is producing a special Catalogue for the Stand, and 5,000 copies will be available free-of-charge to actual and potential buyers of British tools and gauges.

The British Iron and Steel Research Association will hold two Open Days at the Sketty Hall, Swansea, laboratories, on Thursday and Friday, 20th and 21st June, 1957, for representatives of BISRA member firms and users of steel sheet and strip throughout industry.

At the Goring Hotel, Ebury Street, Grosvenor Gardens, Victoria, S.W.1, **The English Electric Co. Ltd.** held an exhibition from the 12th to 14th February to introduce a new range of axially ventilated electric motors covering ½ H.P. to 50 H.P. ratings. These motors are noteworthy since they have standard fixing dimensions to the new British Standards draft specification CW(ELE) 6246, and use Class "E" insulation which permits a temperature rise of 65°C on 40°C ambient temperature. Smaller, lighter and cheaper machines are thus made possible.

The new motors will supersede previous designs of ventilated machines which permitted only a 40°C rise.

A Symposium on Aluminium in Electrical Engineering has been arranged by the **Aluminium Development Association** for Thursday and Friday, May 16th–17th, 1957, at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, by courtesy of the Council of the Institution. Twelve Papers by electrical engineers with experience in using aluminium will be presented.

METALS ICI DIVISION

Graduate senior staff of British nationality are required for the Engineering Group of the Research Department at Witton, Birmingham, to undertake work in the first instance in the following fields :—

1. *MECHANICAL ENGINEER OR PHYSICIST*

for work relating to the strength of metals when subjected to various stress systems. A wide range of conventional testing plant is available. The principal responsibility of senior staff is the development of plant for more complex procedures and the general analysis of the behaviour of materials.

2. *MECHANICAL ENGINEER, METALLURGIST OR PHYSICIST*

to join a newly formed section devoted to the fundamental study of the plastic flow of metals as is encountered in manufacturing operations. The work is primarily of an engineering nature and is separate from, though carried on in association with, the department's work on structural metallurgy and metal physics.

3. *MECHANICAL ENGINEER*

to study the existing and proposed manufacturing processes of the Division. These processes are diverse and almost wholly mechanical in nature. Excellent experimental plant exists for this work, and facilities for the erection and testing of prototype units are at present being extended.

These posts are permanent and hold good prospects of advancement both within the Research Department and in other posts of the organization, to which technically qualified staff are frequently transferred.

Applicants should have a 1st or 2nd Class Honours Degree of a recognized University. Relevant experience is not necessary, although a period of research work either at a University or in industry would be an advantage.

There is a generous salary scale, consistent with the importance of these posts, the starting point depending upon age, qualifications and experience, and there is adequate scope for progressive remuneration.

Excellent conditions of employment include a Contributory Staff Pension Fund and a Profit-Sharing Scheme. On joining the Staff a married man will receive a reasonable refund of removal (including travel) expenses and, where necessary, facilities are available to assist in house purchase.

Write for an application form to the Staff Manager, Imperial Chemical Industries Limited, Kynoch Works, Witton, Birmingham 6, quoting RES/253/ED.

CONTRACTS

Tehran Water Works Authority has ordered from **George Kent Ltd., Luton, Beds,** British Kent water meters for the domestic distribution network throughout the capital. The contract, for 26,000 of the latest ½-inch M2 rotary-piston meters, was negotiated by Kent engineers with the Water Authority and with the Authority's consulting engineers, **Sir Alexander Gibb and Partners.** It is one of the biggest international contracts of recent years for ½-inch water meters, and was won by Kent against extremely keen competition.

Two a.c. electric winder equipments have been ordered from **Metropolitan-Vickers Electrical Co. Ltd.** by **the National Coal Board** for installation in the East and West Shafts of Nine Mile Point Colliery, near Ystrad Mynach, Glamorganshire (No. 5 Area, S.W. Division). The contract is worth about £150,000. The electrical equipment of both winders will be manufactured by Metropolitan-Vickers, the mechanical parts being made by **Robey & Co. Ltd.** and **M. B. Wild & Co. Ltd.** acting as sub-contractors.

Pirelli-General Cable Works Ltd. has received a third order for oil-filled cable for the hydro-electric power station at Kemano, British Columbia, of **The Aluminium Company of Canada Limited.** This company is the principal fully-owned subsidiary of Aluminium Limited. The contract covers the manufacture and installation of a complete 3-phase circuit comprising over 6,000 ft. of single-core 0·4 sq. in. 301 kV oil-filled cable and accessories. The cable will run through a tunnel 670 yd. long from the power station to the terminal of the overhead line which transmits the power to the electrolytic refining plant at Kitimat, 50 miles away. This latest order, to the value of approximately £50,000, was secured in the face of vigorous competition from Canadian cable manufacturers. All negotiations in connection with the contract were carried out in Canada on behalf of Pirelli-General by the **Amalgamated Electric Corporation Limited,** Ottawa.

Airfields of the **Royal Canadian Air Force** are to be equipped with Crash Fire Tenders made in England by **The Pyrene Company Limited.** This contract, valued at approximately one and a half million Canadian Dollars, is the result of months of intensive sales and technical teamwork between the British parent company and its subsidiary in Canada, culminating in a personal visit to Ottawa by the Chairman of the British Company, Mr. F. A. J. Harrison.

British Thomson-Houston Co. Ltd. has secured an order valued at over £2,500,000 for the supply of hydro-electric plant for the Belesar and Eume Power Stations of **Fuerzas Electricas del Noroeste, S.A. (Fenosa)** of Coruna, Spain. For both Stations material to be supplied includes water turbines, sub-contracted to **Boving & Co. Ltd.,** waterwheel generators, with associated transformers, 220-kV and 132-kV switchgear and power station switchgear and control gear.

The award of two contracts, worth £3,750,000 in all, for the construction of tunnels for the North of Scotland Hydro-Electric Scheme and a power station at Kincardine, Fife, was announced by the **Mitchell Construction Company** of Peterborough. The first contract, which is valued at £2½-million, was awarded by the **North of Scotland Hydro-Electric Board** for the construction of over 13 miles of tunnels on the Killin section of the Breadalbane scheme in Perthshire. The second contract, which is worth £1¼-million, was awarded by the **South of Scotland Electricity Board** for work on the new generating station at Kincardine, Fife. The Mitchell Construction Company recently announced the award of a £750,000 contract for the construction of three cooling towers, believed to be the largest in the world, at the Central Electricity Authority's new one million kilowatt power station at High Marnham, Nottinghamshire.

Classified Advertisements

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

PLANNING ENGINEER required by famous company. Should be workshop trained and technically qualified, preferably to HNC standard and have some D.O. experience. Men 25–40 years of age with over 5 years planning experience in any branch of industry will be considered or a shorter period if in electro-mechanical machinery and assembly.

This is a responsible appointment, with good prospects, pension scheme, and a four figure starting salary. Box. 207, The Engineers' Digest.

GIRLING LIMITED
require a Senior Chemist, previously employed in Light Engineering, and experienced in metallurgical analysis, together with finishes, etc., common to this industry.

Successful applicant will be responsible to the Chief Metallurgist for leading a small staff in the chemical laboratory.

Applications to Personnel Manager, Girling Limited, Cwmbran, Mon.

OPPORTUNITIES EXIST for SENIOR DESIGNERS and DESIGN DRAUGHTSMEN
in the Industrial Hydraulics Division of The Plessey Company in one of their new factories at Swindon, Wiltshire. The Company is engaged in the design, development and quantity manufacture of Hydraulic Pumps, Motors, Control Gear and complete installations for a wide variety of industrial applications. Experience in this field is desirable but not essential.

Please reply to the Personnel Manager, The Plessey Company Limited, Kembrey St., Swindon, Wiltshire.

DRAUGHTSMAN required with experience of instruments or light precision engineering. Work is of an interesting and varied nature, with a minimum of supervision to the right man. Excellent working conditions, 3 weeks holiday for men over 26 years of age. A.E.S.D. rates of pay. Five-day week, superannuation scheme, canteen. Please apply in writing, quoting Ref A44 and stating age and experience, to Personnel Officer, Hilger and Watts Ltd., 98 St. Pancras Way, Camden Road, N.W.1.

FIRST CLASS ELECTRONIC SERVICE ENGINEER required to service Industrial Electro Mechanical Instruments throughout the United Kingdom and abroad. Interesting variety of work. Apply in writing with full details, age, qualifications, etc., to Personnel Officer, Davy and United Engineering Co. Ltd., Darnall Works, Prince of Wales Road, Darnall, Sheffield, 9.

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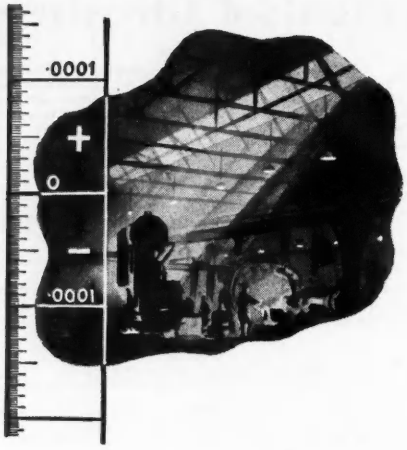

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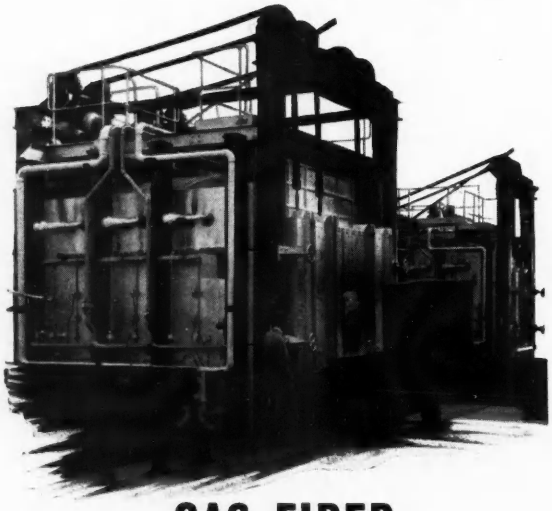

This is part of a plant, installed at Daventry, comprising Two Furnaces, mobile and fixed loading tables and a Gibbons-van Marle Charging Machine.

The Furnace shewn can take work up to 9′6″ diameter x 3′0″ deep.

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BOOKS RECEIVED

Handbook of Welding Design. (Vol. I). Edited by C. Rowland Harman, B.Sc.(Eng.), M.Inst.W. 320 pp., 92 illustrations. Published for The Institute of Welding by Sir Isaac Pitman & Sons, Ltd., London. Price : 45/-.

Compiled under the auspices of a Special Committee of the Institute of Welding, this comprehensive, up-to-date manual covers the design of products fabricated in mild- or low-alloy steels by the metal-arc welding process, and provides for designers a wealth of reliable information on which to base their designs.

Wherever possible, the information in this book is based upon the relevant British Standard or other recognized specification. Where no such authoritative requirements exist, the best British practice is quoted. The workshop aspects of welding are referred to only where the designer can be given guidance to avoid fabrication difficulties by careful choice of design and details. An appendix, indicating the sizes of structures that can normally be transported by rail or road in the United Kingdom, is also included.

This volume, the first of a series of three, provides the designer of a welded assembly or structure with the fundamental data necessary to design a product which is both economical to make and of the required standard of quality. The two other books will deal with the application of the data given in this volume to the design of particular examples taken from practice.

The Oil Engine Manual. Sixth Edition, 1956. Edited by D. S. D. Williams, A.M.I.Mech.E. 384 pp., 153 illustrations. Publishers : Temple Press Limited, Bowling Green Lane, London, E.C.1. Price : 18/-.

Since the publication of the Fifth Edition of this authoritative work in 1950, the fundamental background of oil-engine design has undergone considerable changes. Thus, the number of manufacturers has varied, while power ranges have been made more extensive. This new edition, then, has been largely rewritten, to cater for changes occurring during the past five or six years, and as such, it is fully up to date.

Chapters in the first part of the Manual, which is published in association with "The Oil Engine and Gas Turbine", give the background for engine design (of various forms) for all duties other than marine applications. In the second part, leading details are given of all the current makes of oil engines constructed in the United Kingdom, again for all purposes other than ship and boat duties. The third and final part is a technical appendix, which will be found useful, not only for those concerned with engine manufacture, but for those engaged in the use of such prime movers. Students also will find the whole book of permanent value to them in their work relating to this type of heat engine.

The Nature of Management. Second Edition, 1957. By H. R. Light, B.Sc.(Lond.), F.C.I.S. 160 pp., 25 illustrations. Publishers : Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price : 12/6.

Technical developments make it more and more essential that students of management should read widely and should consider every aspect of the problems with which they are faced. This book is definitely a useful introduction to such reading, inasmuch as its basic purpose is to give a preliminary survey of the field of management and to encourage students to read as widely as possible. This new edition covers the syllabus for " The Nature of Management " paper in the Common Intermediate Examination in Management, and will also be useful for Part III (Industrial Administration) of the Associate Membership Examination of The Institution of Mechanical Engineers, and for Part III (Introduction to Industrial Management) of the Associate Membership Examination of The Institution of Production Engineers.

In this new edition, to which new material on the subject of automation has been added, chapters are included on The Purpose of Management ; Organization ; Purchasing ; Production ; Distribution ; Development ; Personnel ; Control ; and Some Modern Tendencies. In addition, a useful bibliography and index are appended.

Engineering Structural Failures. By Rolt Hammond, A.C.G.I., A.M.I.C.E. 224 pp., 125 illustrations. Publishers : Odhams Press Ltd., Long Acre, London, W.C.2. Price : 25/-.

Structural failure is an enormously important aspect of civil engineering which has been somewhat neglected by writers in this field ; its literature is scattered through many papers and journals, and in numerous reports, not always accessible. The author of this extremely interesting book has satisfied a long-felt want by providing a useful survey of both the causes and the results of failures in a variety of examples over a century of engineering, including earthworks, dams, harbour works, buildings, bridges, and tunnels. He also considers the special problems of failure due to vibration, to earthquakes, and to subsidence, and in welded structures of steel or light alloys.

A final chapter brings out many of the lessons of such failures, making the special point that advances in one branch of engineering may greatly influence work in other branches. This chapter also reviews modern methods of testing materials, ranging from X-ray and electronic developments to the recently completed de Havilland aircraft pressure-test tank. The book emphasizes the importance of scale-model and full-scale research on structural problems, and examples of sound design are quoted.

Among the better-known cases of failure discussed are the Folkestone Warren landslip ; the Bouzey, Marshall Creek, and Dolgarrog dams ; the breakwater failures at Catania, Genoa, and Algiers ; the Knickerbocker Theatre in Washington ; the Tay, Quebec, and Tacoma Narrows bridges ; the Sydney water pressure tunnel, and the Bo-Peep and Arley railway tunnels ; and a number of welded ships.

LATEST INDUSTRIAL LITERATURE

1. Portable Hydraulic Shear. This folder describes a new self-powered hydraulic shear which is independent of all external power supplies. This tool can be handled by one man to the work and will cut steel and iron rods, wire ropes and cables and chains quickly and cleanly, without flash, by arm-power alone. It is especially suitable for Mines, Ships, Constructional and Electrical Engineering and numerous other industries. Five models are now available, with or without remote control, the largest cutting wire ropes up to 2 in. diameter and electric cables up to 3½ in. diameter.

2. Drill Heads. A most useful data sheet written specifically for Jig and Tool Designers is included with the main 4-page brochure describing a range of gearless fixed centre type drill heads. The heads can be produced with any drill pattern required and centre distances can be as small as twice the drill diameter. They are suitable for the production of holes up to ½ in. diameter and can be used for reaming and tapping. Light alloy castings are used to reduce the weight while the stressed components are made of high grade steel.

3. Control Valve. Providing a full bore for a straight-through flow in either direction, this flanged type valve has been designed for the control of abrasive and corrosive slurries, chemicals and vapours. The body and handwheel are cast aluminium and the remaining parts of brass and gunmetal. The slurries, chemicals or vapours are channelled straight through in a special rubber tube, or, where chemical conditions dictate, in suitable synthetic tubes for which replacements are available.

4. Water-Cooled Rotary Louvre Cooler. An entirely new cooler is detailed in a 4-page coloured brochure. Operating on the rotary louvre principle and using water as a cooling medium, the drums revolve on a horizontal axis, the lower arc being immersed in the water bath from which the hollow tapering louvres collect water. The collected water flushes along the louvres in contra flow to the movement of the material, so giving a high degree of heat transfer. The hot material fed in at the centre-line opening forms a moving bed based on its angle of repose, and is assisted in forward movement by the vanes. Various models are available in one, two or three stages and with different dimensions.

5. Reamers. A new range of shell reamers and arbers, solid reamers and boring size reamers are described and illustrated in a neat 8-page booklet. The reamers are supplied ready for use with a 0·0002 in. tolerance to give holes to either B.S.S. or Newall limits without preliminary circular grinding. They are supplied as solid shank cutters up to 1⅛ in. and as shell reamers from ⅞ in. to 2 in. The reamers have a 12 deg. right hand spiral.

6. Honing Machines. An 8-page illustrated catalogue recently published describes three honing machines being made in the United Kingdom under licence from an American company. The smallest model will hone bores from ¼ in. to 1 in. diameter and has a spindle stroke of 3 in. with the option of either hand or fully automatic drive. A second model has a stroke length of 15 in. and is adaptable for bores from 1 in. to 6 in. This model can be provided fully automatic, rotary power feed or hand feed. The third in this range is for bores between 1½ in. and 8 in. and provides a stroke length of 32 in.

7. Automatic Arc Welding. A new method of automatic arc welding evolved from an established process is described in a well illustrated 8-page brochure. A patented type of continuous covered electrode with a newly developed type of covering is used in conjunction with a carbon dioxide gas shield, thus allowing considerably higher welding speeds than can be achieved with flux alone. This new process allows horizontal-vertical fillets of a high standard to be deposited by an automatic open-arc process for the first time.

8. Multiple Way Plugs and Sockets. A 42-page brochure listing a very full range of soldered and solderless aluminium plugs and sockets and indicating correct outlet fittings for every size and type of cable in normal use has just been printed. These connectors are suitable for use with all types of standard cables including those covered by M.O.S. spec. D.E.F.10 and D.E.F.14, type 1B1. A new departure is the availability of accessory sets which are identified against cable types and sizes thus simplifying selection and ordering procedures.

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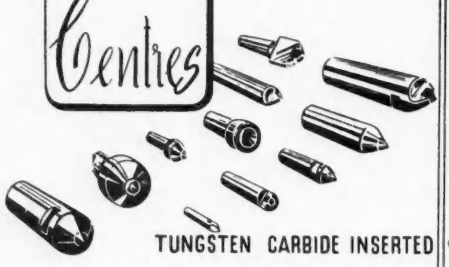

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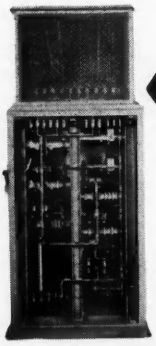
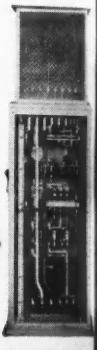
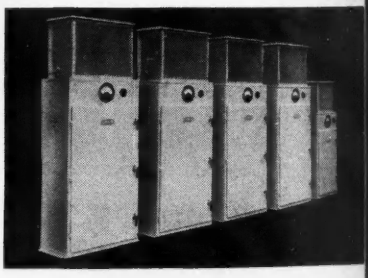


Panel supplied to a large rubber manufacturing firm, to control a 45 H.P. motor for Side-wall Buffing Extraction Process.



Panel supplied to another rubber manufacturer for controlling a 30 H.P. Slip-ring Induction Motor in a laboratory mill.



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